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INSTRUCTION MANUAL

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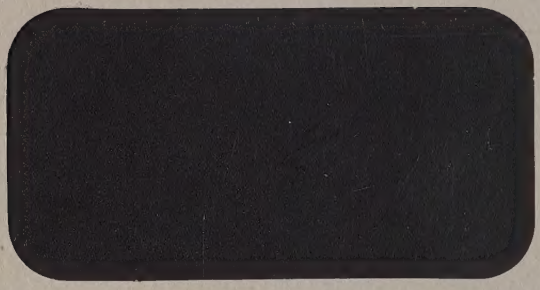

INSTRUCTION MANUAL

VOLTAGE/CURRENT REGULATED
POWER SUPPLY

MODEL KS 60-20 (M)

SERIAL NO. .....

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2,992,379	3,112,439	3,241,042	3,275,948
2,992,386	3,128,423	3,243,690	3,303,411
3,028,538	3,131,344	3,243,749	3,303,412
3,056,905	3,210,619	3,275,925	3,303,415
3,088,053	3,226,628	3,275,927	3,305,763
3,092,757	3,241,054		

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KEPCO, INC. MODEL KS 60-20M

VOLTAGE/CURRENT REGULATED POWER SUPPLY

The Model KS 60-20M is a DC Power Supply that provides highly regulated voltage or current with continuous high resolution adjustments in either mode of operation. Automatic crossover between constant voltage and constant current is provided with a panel indication of the specific operating mode. Accessible terminals enable remote connections for programming or system interconnections with other devices. Built-in forced air cooling with lateral circulation provides positive cooling for continuous operation at any output within the specified ranges.

....DC OUTPUT: 0-60 volts, continuously adjustable;
resolution: 0.05% of maximum output.
0-20 amperes, continuously adjustable;
resolution: 0.05% of maximum output.

....AC INPUT: 104/115/208/230 volts, 50-65 cps, single phase. 1750 watts;
24 amperes at 125V AC.

....CONTROL RATIO: 100 ohms/volt.

....VOLTAGE-COMPARISON-BRIDGE CURRENT: 10 milliamperes.

....AUTOMATIC CROSSOVER

VIX INDICATORS:

A pair of front-panel signal lamps with one lamp lighted during voltage regulated operation, and the other during current regulated operation (internal current sensing only). Crossover from one mode to the other is signalled by the extinction of one lamp and the lighting of the other.

VIX REMOTE SIGNAL:

A pair of rear-panel pin jacks, labelled "V" and "I". Pin V is 8 volts* positive with respect to pin I during voltage regulated operation. Pin I is 8 volts*positive with respect to pin V during current regulated operation. Maximum loading 10 K ohms; must be isolated from ground and the output terminals of the power supply. Crossover from one mode to the other is signalled by an abrupt polarity reversal.

....ISOLATION: Units can be connected in series up to 500 volts between chassis and either output terminal.

*ADD: ± 10%,

CONSTANT VOLTAGE OPERATION: (Specified performance at the rear output terminals)

....LINE REGULATION: Less than 0.01% output voltage change for 115 ± 10V or 230 ± 20V AC line variation, at any output voltage within the specified range.

....LOAD: Less than 0.01% or 0.5 millivolt output voltage change, whichever is greater for NO LOAD to FULL LOAD change at any output voltage within the specified range.

....STABILITY: Output varies less than 0.01% or 3 millivolts whichever is greater over a period of 8 hours after warmup. Measured at constant line voltage, load, and ambient temperature.

....RIPPLE: Less than 1.0 millivolt rms.

....OUTPUT IMPEDANCE: Less than 0.0003 ohm, DC to 100 cps; 0.01 ohm, 100 cps to 1 KC; 0.1 + 0.8 μh, 1 KC to 100 KC.

....RECOVERY TIME: 50 microseconds.

....AMBIENT OPERATING TEMPERATURE: -20°C to +50°C maximum.

....TEMPERATURE COEFFICIENT: Output voltage changes less than 0.01% per °C.

CONSTANT CURRENT OPERATION: (External Sensing)

....CURRENT REGULATED OUTPUT RANGE: 10 milliampere to 100% of maximum rated current.

....VOLTAGE COMPLIANCE: 100% of maximum output voltage (For any selected current value the output voltage is automatically varied from 0 to 100% of maximum output voltage, as required to regulate the output current).

....CURRENT REGULATION:
LINE: Less than 0.01% output current change for 115V ± 10V or 230V ± 20V AC line variation, at any output current within the current regulated range.

LOAD: Less than 0.02% output current change, for maximum change in load resistance at any output current within the current regulated range.

....CURRENT RIPPLE: Less than 0.1% of maximum current rms.

....CURRENT SENSING VOLTAGE; Vs: 1.0 volt across external resistor, R_s.

CONSTANT CURRENT OPERATION: (Internal Sensing)

....CURRENT REGULATED OUTPUT RANGE: Panel controls provide automatic cross-over from constant voltage to constant current from less than 0.5% to 100% of the maximum specified current.

....VOLTAGE COMPLIANCE: From 0 volts to the voltage control setting.

....CURRENT REGULATION:
LINE: Less than 0.02% or 1 milliampere output current change for 115V ± 10V or 230V ± 20V AC line variation at any output current within the current regulated range.

LOAD: Less than 0.02% or 1 milliampere output current change for maximum change in load resistance at any output current within the current regulated range.

....CURRENT RIPPLE: Less than 0.1% of maximum current, rms.

....CURRENT SENSING SAMPLE; Vs: 0.6 volt across internal sensing resistor.

PHYSICAL SPECIFICATIONS:

....DIMENSIONS: 8 3/4"H X 19"W X 20"D.

....WEIGHT: 145 pounds.

....FINISH: Gray Hammertone.

1.2 TERMINALS AND CONTROLS

....POWER: Toggle switch turns power on.

....FUSE, MAIN: Protects input to main power transformer.

....FUSE, REF.: Protects input to reference control transformer.

....VOLTAGE ADJUST: Ten-turn control on front panel for setting the output voltage.

....CURRENT ADJUST: Ten-turn control on front panel for setting the output current.

....INDICATORS: VIX indicators to display voltage or current operating mode.

....OUTPUT TERMINALS: Heavy duty binding posts with 3/4" spacing for output and ground connections.

On Back of Unit:

....OUTPUT TERMINALS: Heavy duty barrier strip for output and ground connection.

....CONTROL TERMINAL STRIP: Sixteen terminal barrier strip for connections to circuit terminals required for special operating applications.

....VIX CONNECTORS: Connecting pin jacks (.08") for remote circuit operation of current/voltage operating mode indicators or process control.

....AC INPUT LINE CORD: Flexible, three-wire line cord, with grounding plug, for connection to AC line. Third wire in cord is grounded to chassis. Connector similiar to Hubbel type #3331-G

1.3 SPECIAL FEATURES

REMOTE ERROR SENSING.- External error sensing terminals located on the control terminal strip allow the error sensing of the output voltage to be performed remotely at the load. This enables the supply to regulate for voltage drops of up to 0.5 volt in each load wire and thereby provide specified regulation directly at the load.

CONSTANT VOLTAGE/CONSTANT CURRENT OUTPUT.- The output may be operated at either constant regulated voltage or constant current. Output controls on front panel enable setting of the automatic crossover from constant voltage to constant current at any current or voltage within the specified ranges. Rear access jacks provide connection to internal control circuits for remote indication of voltage or current mode operation and for control applications. A remote VIX accessory unit is available for connection to these jacks.

CONSTANT CURRENT OPERATION (External Sensing)- By the use of a current sensing resistor of optimum value and a current control resistor, both externally connected, the output can be converted to provide constant current only through a varying load.

PROGRAMMING BY RESISTANCE.- The output voltage can be programmed or controlled remotely by an externally connected resistance. The externally connected resistance will program the output voltage at a constant resistance-to-voltage ratio of 100 ohms-per-volt over the entire specified range of the unit.

PROGRAMMING BY VOLTAGE.- The output voltage can be programmed by another voltage, for special programming application such as Complementary Tracking, Compliance Voltage Extension for Constant Current, etc.

PROGRAMMING CURRENT.- The constant output current function with internal sensing can be programmed by an external control, either voltage or resistance.

PARALLEL OPERATION.- The output of two Model KS units can be connected in parallel across a common load to obtain higher current. Special terminals in the Pass Driver control circuit allow the series pass elements to be parallel driven by a common control signal, automatically providing equal distribution of the current drawn from each supply. Automatic paralleling by means of the crossover characteristic is also possible with no special interconnection.

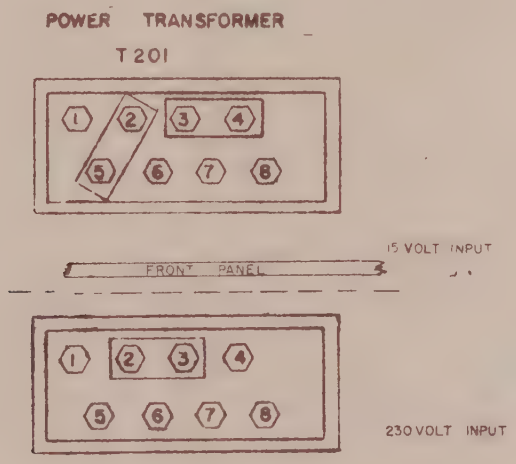
OVERLOAD PROTECTION.- Current limiting automatically limits the output current during overload to the value at which the Current Control is set. In the (internal sensing) constant current mode, voltage limiting automatically limits the output voltage during overload (open circuit) to the value at which the voltage control is set. This allows the supply to continue operating, without damage and without shutting off, during an output overload up to a full short circuit (or open circuit).

2.1 INSTALLATION AND OPERATING INSTRUCTIONS

This Power Supply has been completely inspected and tested at the factory prior to packing, and is shipped ready for installation and operation.

AC POWER.- The Supply is equipped with a three-wire safety line cord and polarized plug. The third (green) wire in the cord, connected to the grounding pin on the plug, is connected to the case and chassis. When using the two-prong receptacle adapter, the green pigtail wire attached thereto must be grounded, to properly ground the power supply.

The Power Supply is normally shipped for 115 volt operation with appropriate fusing. For 230 volt line input, the power transformer, T201, primary windings must be series connected. Remove Power Supply bottom plate and locate terminals at underside of unit. Change connections as shown on diagram for required input voltage.



GROUNDING.- The DC output is isolated from the AC power line and from any direct connection to chassis or ground. The positive side of the output is connected to chassis through a capacitor in series with a resistor. The maximum voltage that can be supported between either output terminal and chassis ground is 500 volts. Either side of the DC may be grounded. Grounding connection is provided at the panel binding post or rear terminal strip.

DC LOAD TERMINALS.- The load may be connected to either the front panel binding posts or to the rear terminal strip. The connecting leads should be carefully constructed, keeping in mind the voltage drops that can develop at high current with wires of insufficient size or poor terminal connections. (See Remote Error Sensing).

COOLING.- The power transistors and rectifier assembly are maintained within proper operating temperatures by a built-in fan, which circulated air laterally through the unit. Be sure all panel openings are clear to permit proper circulation of air.

A protective thermostat, located within a pass transistor assembly, is interconnected with a power relay interlock to remove line power in the event of excessive ambient temperature or a failure in the cooling system. If this action occurs, re-cycling of the power switch is required after proper thermal conditions are restored.

STANDARD OPERATION.- The supply is shipped with six removable jumper links in place between terminals (2)-(3), (4)-(5), (6)-(7), (9)-(10), (11)-(12), (13)-(14), and (15)-(16), on the 16-terminal control terminal strip at the back of the unit. Links must be in place for standard operation.

> NOTE: The terminal screws and links should be tight to insure proper operation. A loose wire connection or jumper link can cause the unit to function improperly. Be sure to put any links that have been removed back in place when changing from one mode of operation to another.

TURN ON.- The Supply may be turned on and off with the front panel Voltage and Current controls turned to any settings without harm.

SETTING OUTPUT VOLTAGE AND CURRENT.- Output voltage and current are both independently adjustable by means of the appropriately labeled front panel controls. Depending upon the load resistance, only one of these adjustments will exercise control. When the VOLTAGE VIX lamp is lit, the voltage control adjustment will control the voltage to the load and the Power Supply will operate as a voltage regulator. In either mode the "other" control will have no effect on the output except to act as a limit.

In voltage regulation mode, load current increases with decreasing load resistance until the setting of the current control adjustment has been reached. At this point the Power Supply will crossover into current regulation mode. The voltage VIX lamp is extinguished and the current VIX lamp is lighted.

If crossover is not desired within the rated output voltage and current range of the power supply, the inoperative control should be set fully clockwise so that its limiting point is outside of the operating range. In practice, set the controls so the desired VIX lamp remains lighted throughout the range of desired loads.

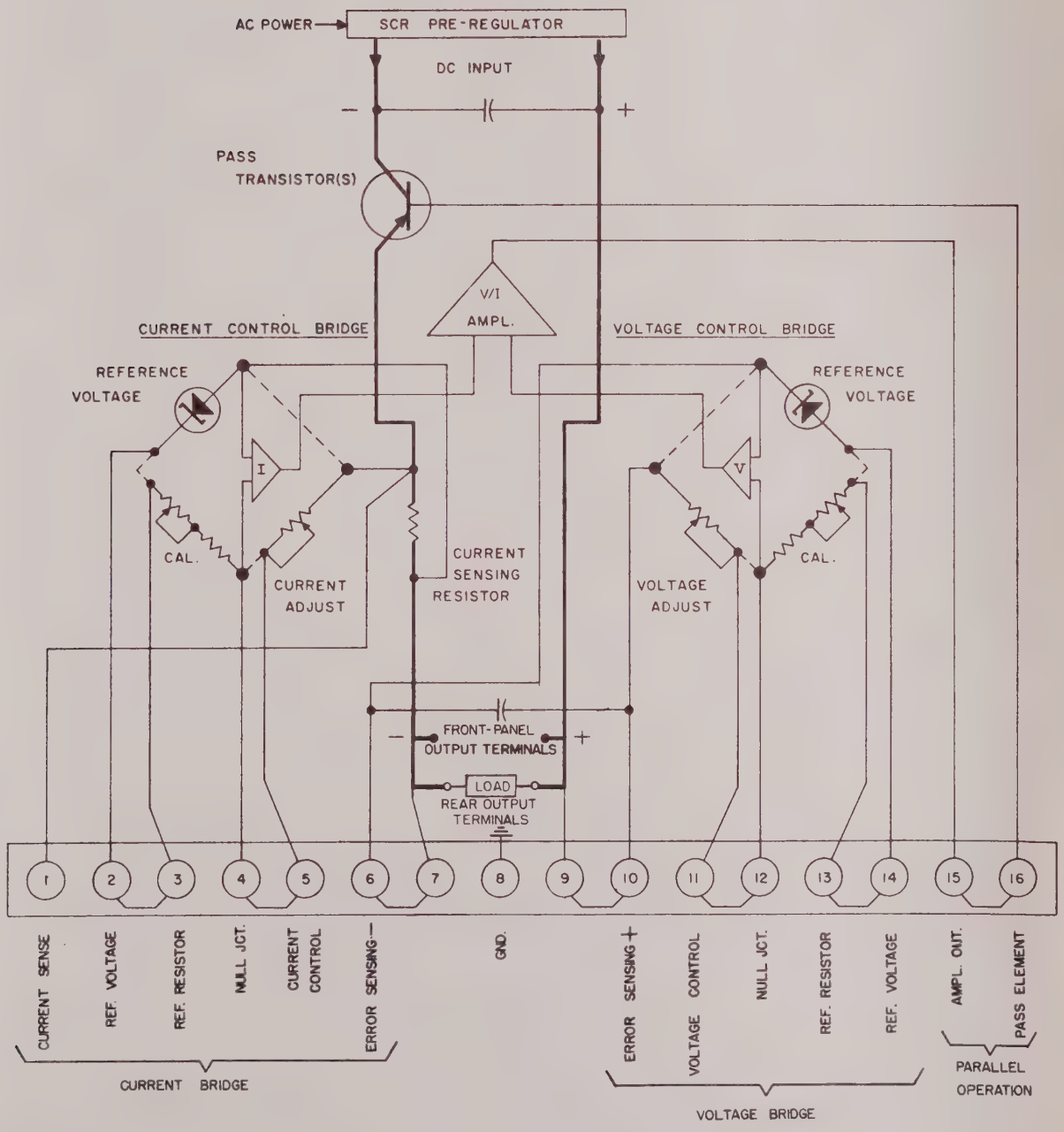
2.2 SPECIAL OPERATING PROCEDURES

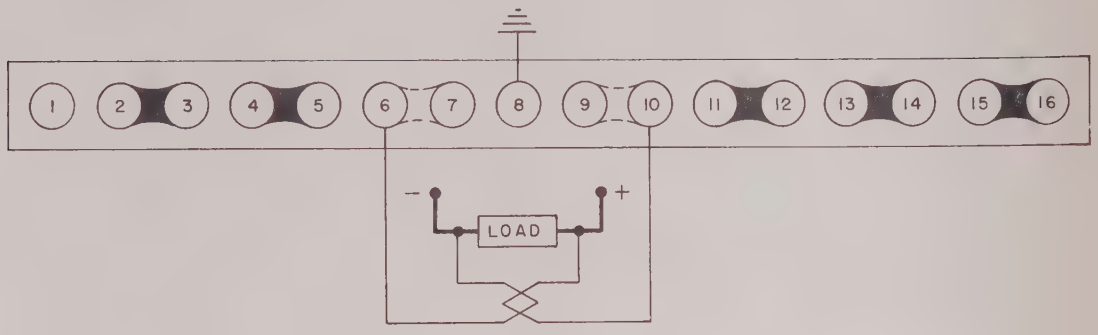
Complete accessibility to the power supply's internal control elements is provided by the 16-terminal connector at the rear of the unit. On the following pages of this section are described a group of special connections that enable control of the power supply by external means.

Included herewith is a simplified diagram of the basic internal control circuits shown in relation to the accessible terminal connections for ease in understanding the overall operation.

SIMPLIFIED DIAGRAM OF MODEL KS AUTO-CROSSOVER POWER SUPPLY

WITH REAR TERMINAL CONNECTION DETAIL





Shielded Twisted Pair

The Error Sensing terminals are the input terminals to the Supply's regulating system for sensing changes or errors in the output voltage being regulated. Normally, the Error Sensing is connected to sense the output voltage directly at the rear output terminals. Connected in this manner, specified regulation will appear at these terminals while the voltage at the load will be reduced by voltage drops due to the resistance in the wires between the output terminals and the load.

The Error Sensing input can be connected to sense the voltage directly at the load, thereby maintaining optimum regulation at the load instead of at the Supply's terminals. Up to 0.5 volts drop in each load connecting lead can be compensated by using Remote Error Sensing.

PROCEDURE:

1. Remove the two Remote Error Sensing jumper links connected between terminals (6)-(7) and (9)-(10) at the back of the unit. These links provide error sensing of the voltage at the Supply's terminals and must be in place when Remote Error Sensing is not used.

2. Using a twisted wire pair, separated from the main load connecting wires, connect the Error Sensing terminals (6) and (10) to the DC terminals at the load. Be sure to maintain polarity, i.e., connect the Positive Error Sensing (10) to the positive side of the load, and Negative Error Sensing (6) to the negative side of the load. The Remote Sensing wires are used to transmit voltage only and do not carry load current. There is a constant current (bridge current) flowing through the Remote Sensing wires.

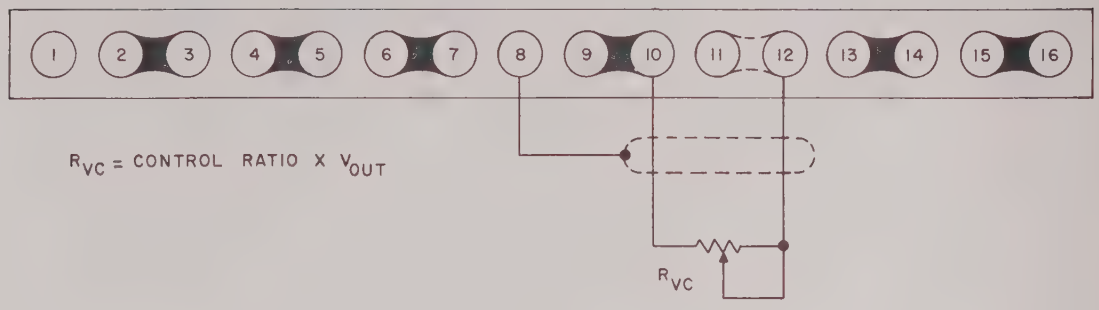
   NOTE: The unit should never be allowed to operate with an open circuit between the Remote Error Sensing terminal and its respective output terminal. An open connection

will degrade the regulating function and cause the output voltage to rise. A pair of diodes internally bridge the error sensing connections, limiting the output voltage rise to approximately 1.5 volts. Output ripple is increased sharply, also.

When operating the power supply with remote error sensing, do not permit the load connecting wires to become disconnected from the load while the error sensing leads remain connected. If this occurs, the power supply will attempt to maintain current flow through the sensing lead and damage to the power supply may result.

Twisted wires for the load connecting leads should be used to reduce transient recovery time and enhance stability of operation.

PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL RESISTANCE



The output voltage may be programmed, or controlled, over its entire range by means of an externally connected resistance. The external control may be continuously adjustable or stepped, and may be remotely located. When connected, it will function in place of the front panel Voltage Adjust control.

The static, or steady state, current through the programming resistance is equal to the bridge current of the model: the reciprocal of the programming ratio, or 1 ma for 1000 ohm/volt units, 10 ma for 100 ohm/volt units.

The external resistance will control the output voltage at an ohm/volt control ratio specified for the Model. The exact control ratio is adjustable a small amount around the specified value in order to permit adjustment for component tolerances. This is done by means of the internal Maximum Voltage Adjust resistor. The control ratio will remain constant over the entire output range of the unit. It is usually adjusted, either for internal or external control, at maximum rated output voltage. (See Internal Adjustment Procedures).

PROCEDURE:

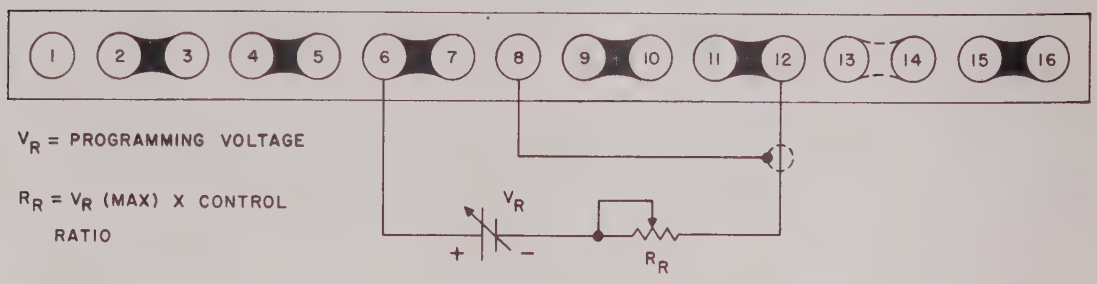
1. Remove the jumper link connected between terminals (11)-(12) on the back of the unit. This disconnects the internal Voltage Adjust control from the circuit.

2. Using shielded, twisted-pair wire, connect the external programming resistance to terminals (10)-(12). Connect the shield to the chassis, terminal (8).

If fixed values of resistance are to be switched for stepping the voltage, the switching device should have shorting contacts (make before break) so the circuit does not open during transfer. Programming large excursions of voltage by switching contacts or other rapid switching means, requires the use of high wattage resistors for the lower voltages that are programmed.

These are necessary to absorb the higher voltage charge stored in the output capacitors. Similarly, manually operated or servo driven potentiometers of low current capacity must be restricted in their speed of rotation by friction or other means to prevent potentiometer burn-out. These precautions are particularly significant when the supply is lightly loaded.

PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL VOLTAGE



The output voltage of this model can be controlled by an external voltage source. The output voltage of the supply will follow in constant proportion the voltage of the programming source for an approximate 10:1 change in output.

The proportion between the two voltages will be constant, but adjustable. It is determined by the proportion established between the resistance of an added external coupling resistor (R_r) and the resistance at which the output voltage control potentiometer (R_{vc}) is set. The proportion may be set at unity (1:1) in which case the output voltage will be equal to the programming voltage, or it may be set for any other ratio, within the voltage capabilities of the unit.

This mode of programming may be used in conjunction with an external Voltage Control resistance (See Programming Output Voltage by External Resistance) to provide programming control of both the magnitude and the ratio of the voltages.

It is required that the positive side of the programming voltage source be connected to the negative side of the programmed voltage. Also, the programming source must be capable of providing a maximum control current equal to the reciprocal of the control ratio for the Model.

PROCEDURE:

1. The proportion maintained between the output voltage and the programming voltage is expressed very closely by the following:

$$\frac{V_o}{V_r} = \frac{R_{vc}}{R_r}$$

where: V_o = output voltage to be programmed.

V_r = Programming voltage.
R_{VC} = Voltage Control resistance (internal or external).
R_r = External coupling resistor.

2. a. The values of V_o and V_r are usually given by the requirements of the particular application.

b. The value of R_r is determined by the Control Ratio for the model using the programming voltage at its maximum value:

R_r = V_r (max.) X Control Ratio (ohm/volt)

c. R_{VC} is equal to V_o X Control Ratio.

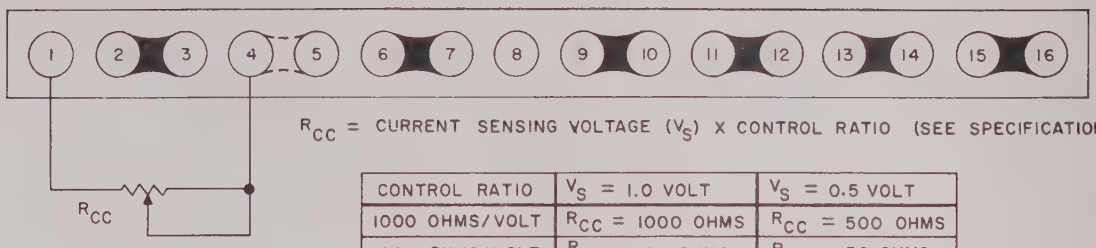
3. a. Connect the positive side of the programming voltage (V_r) to terminal (6). Using shielded wire, connect the external coupling resistor (R_r) between the negative side of V_r and terminal (12) on the programmed supply; connect the shield to ground (8).

b. Remove the jumper link connected between terminals (13)-(14) on the programmed supply.

c. On the programmed supply set the voltage control (either internal or external) approximately for the maximum value of voltage to be programmed.

d. Turn on the programmed supply and the programming voltage source. With the programming voltage set to its maximum value, adjust the voltage control on the programmed Power Supply to establish the desired ratio. The programmed output voltage should track variations in the programmed voltage at the proportion established over a range of 10:1 change in output. If a wider range of tracking is desired, it may be necessary to re-establish the ratio of output to control voltage at a lower value.

PROGRAMMING OUTPUT CURRENT WITH EXTERNAL RESISTANCE



R_{CC} = CURRENT SENSING VOLTAGE (V_S) X CONTROL RATIO (SEE SPECIFICATION)

CONTROL RATIO	V_S = 1.0 VOLT	V_S = 0.5 VOLT
1000 OHMS/VOLT	R_{CC} = 1000 OHMS	R_{CC} = 500 OHMS
100 OHMS/VOLT	R_{CC} = 100 OHMS	R_{CC} = 50 OHMS

In this mode of operation an external resistance is connected to the unit to function as a Current Adjust control in place of the front panel control. The external control may either be fixed, stepped, or continuously variable, and may be located remotely from the Power Supply. If fixed values of resistance are to be switched, for stepping the current, the switching device should have shorting contacts (make before break), so the circuit does not open during transfer.

C A U T I O N

The Current Adjust control on the front panel is set by an internal adjustment so that at its maximum setting the maximum output current will be limited to a value slightly above the rated maximum current for the particular Model. When an external resistance is used it must be similarly adjusted at maximum, and the front panel control readjusted when returning to normal operation. (See Internal Adjustment Procedures)

PROCEDURE:

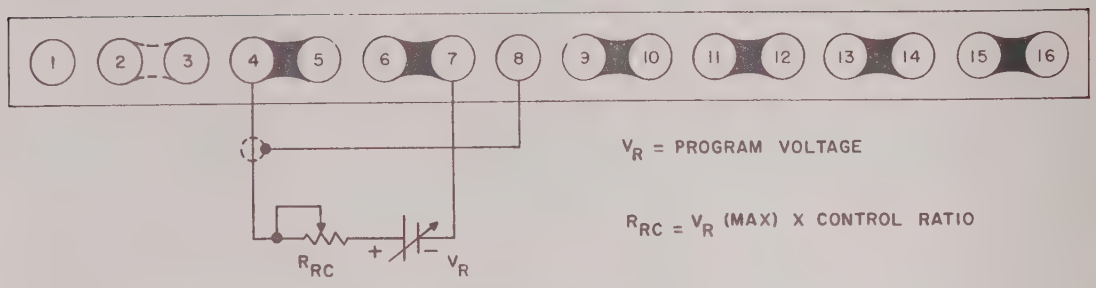
1. Using shielded, twisted-pair wire, connect external resistance to terminals (1)-(4); connect the shield to ground (8). Remove the jumper connected between terminals (4)-(5); this disconnects the front panel Current Adjust control from the circuit.

2. For continuously variable control, the external resistance should have the range as specified. This will have to be adjusted at the maximum setting before operation.

3. For step function control fixed resistance values can be approximated, subject to exact calibration of the current, by proportioning the maximum range in ohms for the fraction of maximum rated current to be programmed.

4. Adjust the external control in accordance with the Procedure for Internal Maximum Current Adjust.

PROGRAMMING OUTPUT CURRENT WITH EXTERNAL VOLTAGE



In this mode the output current is controlled by an external programming voltage. The voltage may have any value and is coupled to the unit through an externally connected resistor (R_{rc}). This resistor is determined by multiplying the maximum programming voltage by the control ratio for the Model. The actual resistor used should be adjustable, and should have a slightly higher (10%) value than calculated. It must be adjusted, at the maximum programming voltage, to calibrate for maximum current thereby preventing the maximum rated current from being exceeded.

PROCEDURE:

1. In order to calibrate the external coupling resistor (R_{rc}), the power supply must be pre-set with a load for maximum rated output current. With the front panel voltage and current controls both set to maximum, connect an adjustable load to the unit and set it to draw exactly the maximum rated current for the model. Leave the front panel controls and the load at that setting and turn the unit Off.

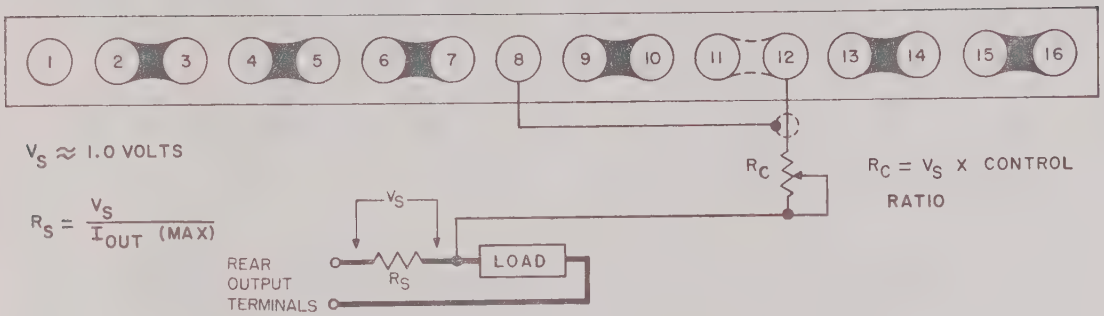
2. Remove jumper between (2)-(3). Connect the negative side of the programming voltage to terminal (7) on the back of the unit. Connect one end of the external coupling resistor, (Rrc), to the positive side of the programming voltage, and the other end to terminal (4).

3. With the programming voltage set to its maximum value, calibrate the maximum current as follows:

   a. Set the external resistor R_{rc} to its highest value.
   b. Turn the programming source and the power supply on. With R_{rc} at the higher resistance setting, output current should be some value below rated maximum. Adjust R_{rc} in the direction of decreasing resistance, increasing output current until rated maximum is obtained.

4. Varying the programming voltage down from its maximum value should vary the output current proportionately.

PROGRAMMING OUTPUT CURRENT
WITH EXTERNAL SENSING



The output of the unit can be converted to provide constant current through a varying load with external current sensing. Current regulation of a high order can be achieved by optimizing the current sensing resistor for the lower values of output current.

In this mode the voltage control bridge of the power supply is being used to regulate current. The current bridge is disabled and consequently automatic crossover action does not occur and the voltage VIX indicator lamp will be lit.

A current sensing resistor, R_S, is connected to the output in series with the negative side of the load. A voltage, V_S, directly proportional to output current will be developed across R_S.

A current control resistor, R_C, is connected between the load end of R_S and the programming input terminal, (3). A constant current derived from the Power Supply's internal fixed reference voltage flows through control resistor R_C. This current is constant and determined entirely by the internal reference circuit, independent of the value of R_C and of output current. The voltage (V_C) across R_C will be equal to the resistance of R_C times 1/control ratio and will be constant at that value.

The regulating system in the supply will act to control current to the load so as to maintain the voltage V_S, across the sensing resistor equal to the constant voltage V_C, across the control resistor. By maintaining the voltage across R_S at a constant value, output current is maintained constant. For V_S a nominal 1.0 volt is recommended as a practical value, requiring that the resistance of R_C be equal to 1000 ohms for CK models and 100 ohms for KS models. By using a variable resistor for R_C, the voltage across it can be adjusted, providing a convenient means of varying the output current. This provides a variable range of current for any one value of sensing resistor, and allows the use of more readily available standard values of resistors for current sensing.

NOTE: R_c determines the sensing voltage that will be maintained across R_s. Varying this voltage varies the output current. However as this voltage is decreased, current regulation is degraded gradually and operation at sensing voltages below 0.1 volt is not recommended. A nominal 1.0 volt is chosen to be a practical value. Higher voltages do not appreciably improve regulation, while they do increase the dissipation requirements of the sensing resistor, and take more compliance voltage from the load.

PROCEDURE:

1. Determine the value of R_s on the basis of 1.0 volt divided by the maximum value of constant current that will be required. The resistor selected should have a power rating at least ten times its actual dissipation requirement, and should have a low temperature coefficient.

   If the exact resistance calculated for R_s is an impractical value, use the nearest lower value available and adjust the current to the exact value required with the current control resistor, R_c.

2. Connect R_s in series, between the negative DC output and the load. Connect the current control resistor, (R_c), between the load end of R_s and the terminal (7) at the rear. Remove the jumpers connected between terminals (11) and (12).

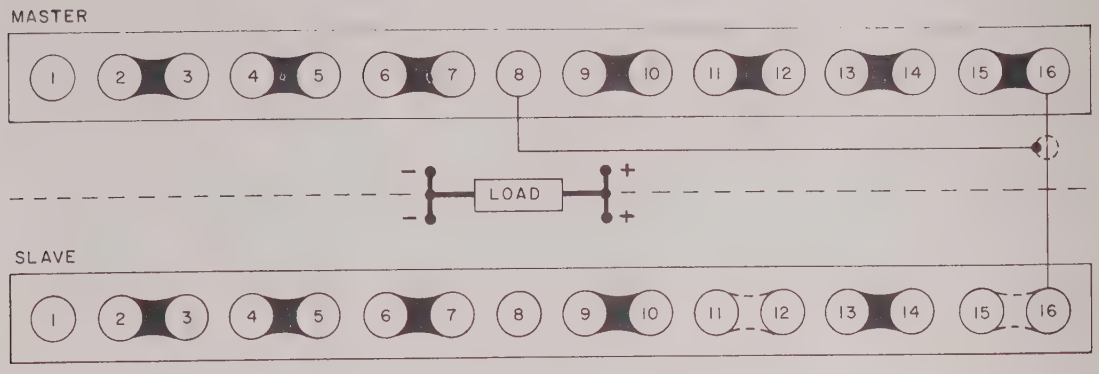
3. To prevent the internal current function from interfering with this external sensing mode, the Current Adjust control on the front panel should be turned to its maximum, fully clockwise position. This circuit may be more positively deactivated by disconnecting the jumper link on terminals (4)-(5) at the rear.

4. With the supply turned on and loaded, adjust the current control resistor to obtain the required value of output current. R_c may require resetting until the resistor temperature comes to equilibrium.

C A U T I O N

When using the external sensing mode of constant current operation it is important that the load not be allowed to achieve a value that will, at the current being drawn, attempt to develop a voltage across the output exceeding the rated maximum output voltage of the Power Supply. The voltage across the output will be equal to the product of the total resistance across the output (load resistance plus sensing resistor) times output current. In the external sensing mode of current regulation the output of the supply does not crossover into constant voltage at maximum output. Consequently if the output voltage is permitted to exceed rated maximum, the regulating function of the supply becomes depreciated.

PARALLEL OPERATION (MASTER-SLAVE)



Two identical models may be paralleled in a master-slave connection to obtain higher current. In this arrangement, the pass transistors of both units are effectively in parallel with a common control derived from the master supply amplifier. (See note on following page)

1. Remove jumpers (11)-(12) and (15)-(16) on the slave unit. Join terminals (16) of both units with a shielded wire and connect the shield to terminal (8) on the master unit.

2. Connections to the load should be made with equal lengths of conductor from each power supply to insure optimum current sharing. Join front terminals only, or rear terminals only, to the load to further assist equal sharing of load current.

3. Remote error sensing, when used, is connected to the Master unit in a manner as prescribed under REMOTE ERROR SENSING.

PARALLEL OPERATION (AUTO-CROSSOVER)

The AUTO-CROSSOVER mode of parallel operation is unique with this class of equipment, and involves no special interconnection except to connect each Power Supply to the common load through approximately equal lengths of load connecting wire.

The voltage across a light load, will be controlled by whichever Power Supply has the higher voltage setting. Up to its current limit setting, this Power Supply will deliver all of the load current. The Power Supply with the lower voltage setting will idle at zero current until the current limit point of the first supply is reached by the load. At this point the first supply will switch to current regulation at its limit value and the load voltage will start to fall. The voltage will fall only to the voltage setting of the second supply whereupon this Power Supply will begin to deliver current to the load and will control its voltage. The current through the load will be the sum of the current from each supply.

The two voltage controls on the paralleled Power Supplies should be set as close together as possible, minimizing the small voltage drop when Supply No. 1 switches to current regulation. When the two voltage controls are set to the same voltage, the Power Supplies will share the load and the relative current from each Power Supply can be controlled by adjusting the relative settings of the voltage controls.

When two paralleled power supplies are set to widely different voltages, and the supply with the higher setting is in control, a current flow is set up through the voltage control of the idle supply equal to the output voltage divided by the resistance of the voltage control setting of the idling supply.

To prevent this current from becoming excessive, a minimum setting of the lower voltage control must be observed. A minimum of 1/10th the setting of the higher (controlling) voltage control is recommended.

Do not allow the lower setting to approach zero since the current can become large enough to damage the control.

Note: For either of the foregoing methods of parellel operation, simultaneous application and removal of line power is required.

2.3 INTERNAL ADJUSTMENT PROCEDURES

Internal circuit adjustments for output voltage and current are contained in the Supply. These are preset at the factory and should require readjustments only following the replacement of a circuit related component, or when required in conjunction with one of the special programming applications.

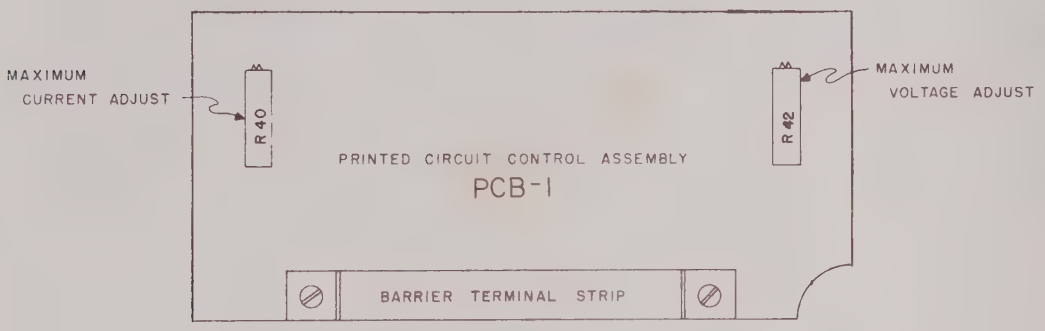


Figure 2.3-a LOCATION OF ADJUSTING CONTROLS FOR MAXIMUM CURRENT AND VOLTAGE

The controls are located on the printed circuit control assembly as shown in Figure 2.3. Access to the controls is made by removing the top and rear cover plates from the Power Supply.

1. Maximum Voltage Adjust.- This adjusts the constant current ratio between the resistance of the Voltage Control, either internal or external, and the output voltage. This control ratio is intended to have a nominal value of 100 ohms per volt, but is made adjustable around that value to allow exact setting of the output voltage to the Voltage Control resistance.

   a. To adjust for the front panel Voltage Control, turn both front panel controls, Voltage and Current to their maximum (clockwise) position. With no load connected, turn the Maximum Voltage Adjust to obtain an output voltage approximately 2% higher than the rated maximum.

   b. To adjust for an external control, first set the external control to its maximum position, and turn the Maximum Voltage Adjust to obtain an output voltage equal to the maximum resistance of the external control divided by 100. This value can be 2% higher than the rated maximum output voltage of the unit.

2. Maximum Current Adjust.- This sets the upper end of the range for the Current Adjust control at the front panel (or an external control, if one is used). It is adjusted so that the Current Adjust control when set to its maximum, will not

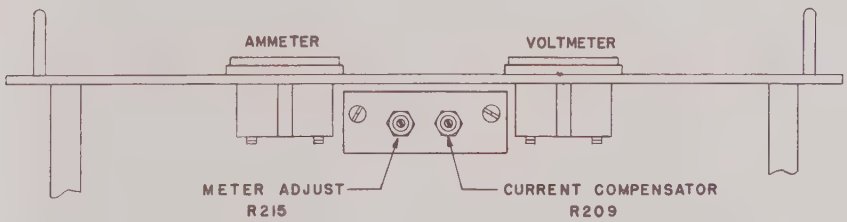
produce more than approximately 2% higher than the rated maximum current.

a. Connect a variable load to the output through an accurate external ammeter.

b. Set the output voltage to maximum rated output voltage; turn the Current Adjust control to its maximum (clockwise) position; turn the Maximum Current Adjust to maximum clockwise position.

c. Starting from no-load, increase load current to obtain an output current approximately 2% higher than rated maximum. Adjust the Maximum Current Adjust to obtain an output current approximately 2% higher than rated maximum.

The following adjustments are factory made and should not be disturbed unless required by a component change.



(METERED MODELS ONLY)

Figure 2.3-b LOCATION OF CURRENT COMPENSATOR AND METER ADJUST

A current compensation adjustment is mounted behind front panel as shown in Figure 2.3-b. For models with output current of 24 amperes and higher an ammeter calibration control is included on the same mounting assembly.

3. Current Compensation (Constant Current Mode)

Adjustment Control R209 coupled with R210, R54, and R55 compensates for the internal loading of the voltmeter and voltage bridge circuit in constant current operation. Without this compensation, constant current regulation is degraded.

The initial adjustment of R209 is made at the factory and would require re-adjustment only after a component change or where a significant change is made in internal loading.

The adjustment is made at a load current of 10-20% of maximum current to achieve best resolution of setting. A differential voltmeter with better than one millivolt resolution is required to measure a voltage drop of

approximately one volt across a current measuring resistor of suitable value (see page 4.1-2). A test load resistance, across which is connected a shorting switch, is used to introduce maximum compliance excursion for the measurement.

With the shorting switch engaged and current flowing through the measuring resistor set the differential voltmeter to zero. Dis-engage the shorting switch and note deflection on meter. Rotate R209 to minimize this deflection on repeated tests.

4. Ammeter Adjust (25 ampere models and up)

Connect an external, calibrated ammeter and variable load to the supply and adjust load current to equal maximum rated value. Rotate R215 to adjust deflection of panel ammeter to this value.

5. PRE-REGULATOR ADJUSTMENT

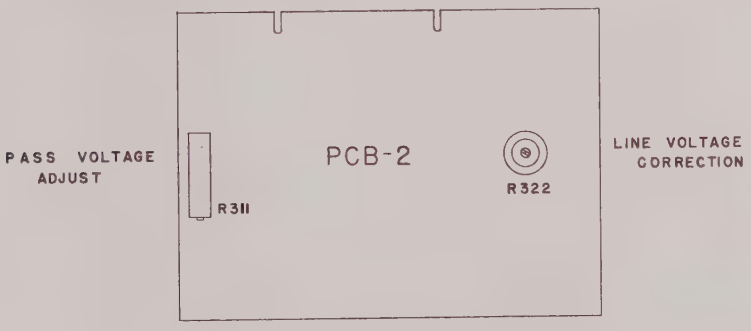


Figure 2.3-c LOCATION OF ADJUSTING CONTROLS FOR PRE-REGULATOR

INSTRUMENTS REQUIRED:

(a) Oscilloscope, Tektronix Model 502 or equal.
(b) Voltmeter, 20 K ohms/V, Weston Model 980 or equal.
(c) Variable Resistive Load, Kepco Model 6212 or equal, to fully load power supply.
(d) Line Voltage Adjustor, Kepco Model 920B, or variable auto-transformer.
(e) Shorting Switch - heavy duty, or Circuit Breaker.

PROCEDURE:

(1) Connect Resistive Load to output terminals of Power Supply under test, in parallel with Shorting Switch. Leave Shorting Switch open.
(2) Connect Voltmeter across Pass Elements, between Collectors (minus) and junction of emitter resistors (plus). Note: In sixty volt units, which have two sets of pass elements, connect across the main (NOT the slave) group of pass elements only.
(3) Connect the Scope Leads across the conductor which connects the cathode(s) of the SCR(s) to the positive terminal of the input capacitor. This wire (or buss bar) then becomes a low value sensing resistor for the observation of current pulses. Caution -- to avoid ground loop shorting effects,

differential input operation of the Scope is recommended.

(4) Connect the Power Supply line cord to the Line Voltage Adjustor, and set input to 105V.

(5) Set R322, the Line Voltage Correction Adjustment to its maximum counter-clockwise position and set R311, the Pass Element Voltage Adjustment to approximately the center of its range.

(6) Turn on the Power Supply and set to maximum rated output voltage.

(7) Slowly increase the load until maximum output current is reached while observing the voltage across the pass elements (Vx) on the voltmeter. If this voltage tends to fall below 2 volts, readjust R311 to maintain it above this value; otherwise loss of regulation will occur.

(8) When maximum rated output current is reached, adjust the Power Supply front panel current control to put unit on the current mode (Eo max., Io max.).

(9) Adjust the Scope controls so that a regular series of current pulses are observed.

(10) Adjust R311 so that the pass voltage (Vx) is set to approximately 3 ± 0.2 volts.

(11) Using the 920B Line Voltage Adjuster, (or equal) change the input from 105V to 125V and note the change in Vx as read by the meter.

(12) Return the input to 105V. Turn R322 slightly clockwise (increase). Vx will change, since R322 and R311 interact. Readjust R311 to return Vx to its proper value.

(13) Again change the line input to 125V, while noting the change in Vx. Check the current pulse waveform on the Scope for any sign of irregularity or instability.

(14) Repeat procedure as outlined in Paragraphs 12 and 13 until the change in Vx (ΔVx) is set at the minimum value which still allows stable operation. Irregularity or lack of symmetry of the current pulse waveform as displayed on the Scope indicates that R322 should be backed off slightly (counter-clockwise).

(15) When above adjustments are completed, short the output by closing the shorting switch, and again measure ΔVx as the line input voltage is varied between 105V and 125V.

(16) Some <u>over</u>-regulation may be observed; that is, Vx may <u>increase</u> as line voltage is <u>lowered</u> and vice versa.

(17) If over-regulation is noted at short-circuit, R322 and R311 should be readjusted to make the <u>under</u>-regulation increment, ΔVx, at maximum output voltage, approximately equal to the over-regulation increment, ΔVx, at short-circuit. Several successive readjustments may be required.

SECTION 3.0 CIRCUIT DESCRIPTION

See Diagram on Page 3.1-2

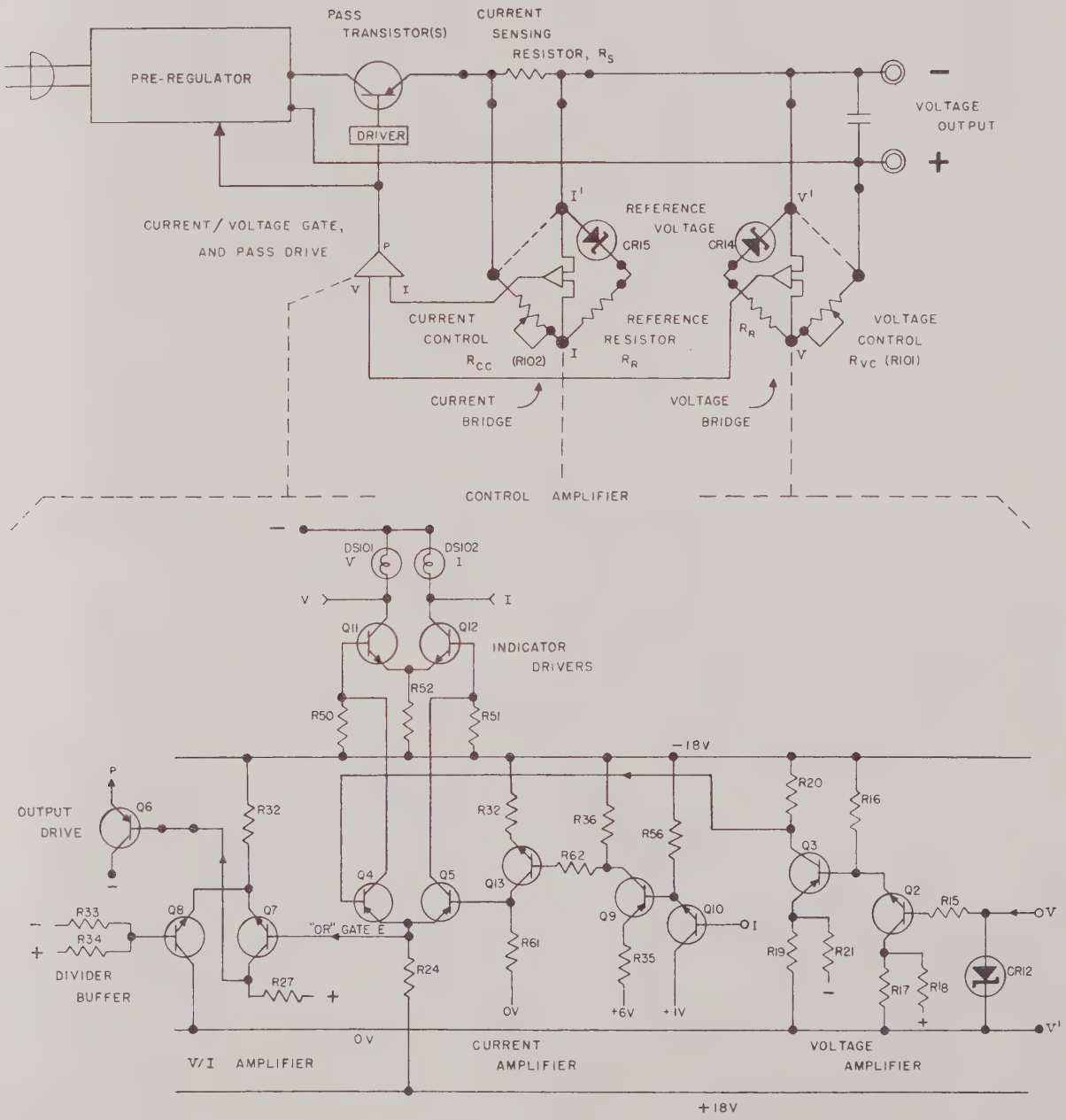
The automatic voltage/current crossover characteristic of the KS series entails two separate control channels each with its comparison bridge circuit and associated error amplifier. In voltage mode operation the VOLTAGE BRIDGE senses the voltage at the power supply terminals (or load terminals in remote sensing) and compares this voltage to a zener reference voltage. Through voltage proportioning resistors R_r and R_{vc} a control signal is produced at V, V' and amplified by Q2 and Q3.

For current mode operation the CURRENT BRIDGE senses the voltage drop across the current sensing resistor, R_s, and compares this voltage to a zener reference voltage. Through voltage proportioning resistors R_r and R_{IC} a control signal is produced at I, I' and amplified by Q9 and Q10.

Output of each amplifier is directed to an 'OR' type gate which determines the mode of operation for control of the pass transistors. This gate consists of Q4 and Q5 with their emitters connected to a common resistor at E. The voltage at point E reflects the higher voltage level between the current and voltage amplifier outputs. From this point the control signal is amplified by Q7 and coupled to the pass driver by emitter follower, Q6.

The operating mode of the system is mutually dependent upon the voltage control setting, the current control setting, and the load resistance. The characteristic crossover point is uniquely defined by that ratio of the voltage and current setting which equals the load resistance (crossover resistance).

For a visual indication of the mode of operation, VIX panel indicators V and I are included. These are driven by transistors Q11 and Q12. Access to these drivers are provided for remote indication and for control applications by standard pin jack connections located at the rear. A $\pm$ 8 volt excursion occurs during the crossover transition.


PASS TRANSISTOR(S)
CURRENT SENSING RESISTOR, R_S
PRE-REGULATOR
DRIVER
VOLTAGE OUTPUT
CURRENT/VOLTAGE GATE, AND PASS DRIVE
REFERENCE VOLTAGE
CR15
CR14
CURRENT CONTROL R_{CC} (R102)
REFERENCE RESISTOR R_R
VOLTAGE CONTROL R_{VC} (R101)
CURRENT BRIDGE
VOLTAGE BRIDGE
CONTROL AMPLIFIER
DS101
DS102
INDICATOR DRIVERS
Q11
Q12
R50
R51
R52
-18V
OUTPUT DRIVE
Q6
R32
R33
R34
DIVIDER BUFFER
Q8
Q7
"OR" GATE
Q4
Q5
Q13
R61
R24
R27
R62
R36
R56
Q9
Q10
R35
R20
R16
Q3
Q2
R15
R19
R21
R17
R18
CR12
0V
+6V
+1V
+18V
V/I AMPLIFIER
CURRENT AMPLIFIER
VOLTAGE AMPLIFIER

SECTION 3.0 CIRCUIT DESCRIPTION: PRE-REGULATOR

The Model KS pre-regulator system is designed to maintain a minimum, controlled voltage across the transistor pass elements. This function may be likened to a coarse control ahead of the transistor pass elements, which serve as the fine control. In this way minimum pass element dissipation is achieved with resulting greater overall efficiency.

A simplified diagram of the system is shown on page 3.1-4. Three combinations of rectifiers and SCR's to form full wave rectification are shown. The essential operating principle to be described is the same for any of the combinations.

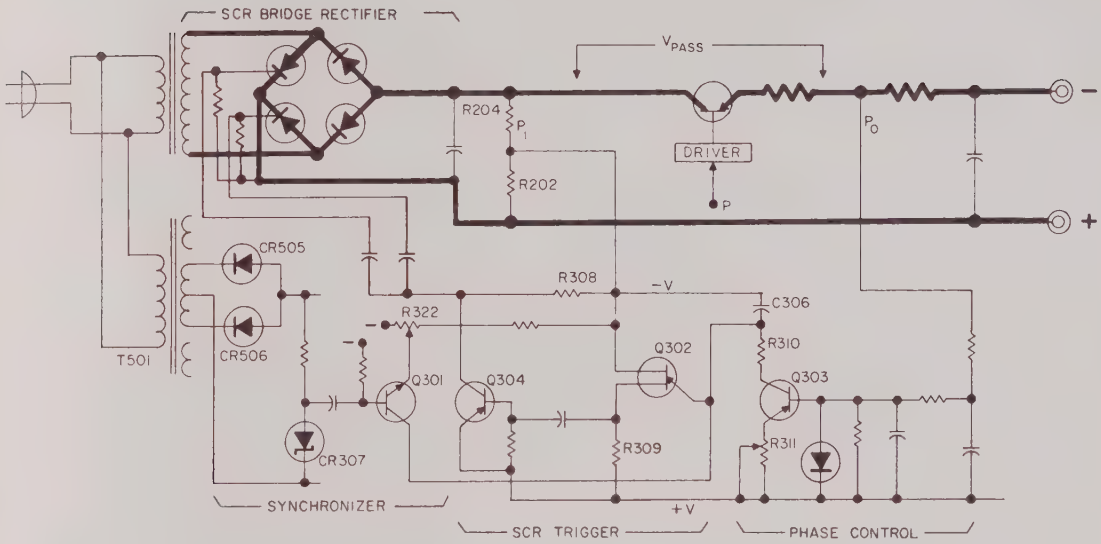
Input to the pre-regulator is derived from PI-PO, consisting of the drop across the pass elements plus a component of voltage from the divider resistor R204. This component reduces the loop gain variations over the total voltage excursion, resulting from an essentially linear control operating on a sine wave power source.

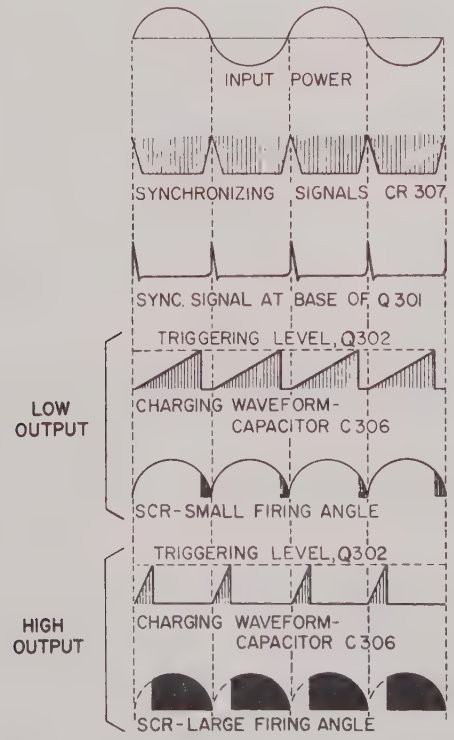
A variation in voltage across PI-PO, reflecting a change in line, load, or voltage control setting, alters the conduction of Q303 to change the charging rate of "ramp" capacitor C306. At a specific potential across C306, uni-junction Q302 triggers, supplying a negative pulse to Q304 amplifier. The positive excursion generated at the collector of Q304 feeds the gate electrode(s) of the SCR(s) to switch power into the system.

The combination of C306, R310, Q303, and R311 constitute a "ramp" timing system, with the slope of the ramp a variable factor dependant upon the base signal at Q303 and the setting of R311. An increasing voltage drop at PI-PO reduces conduction through Q303, thereby reducing the ramp slope and, correspondingly, the SCR firing angle to lower the voltage at PI-PO.

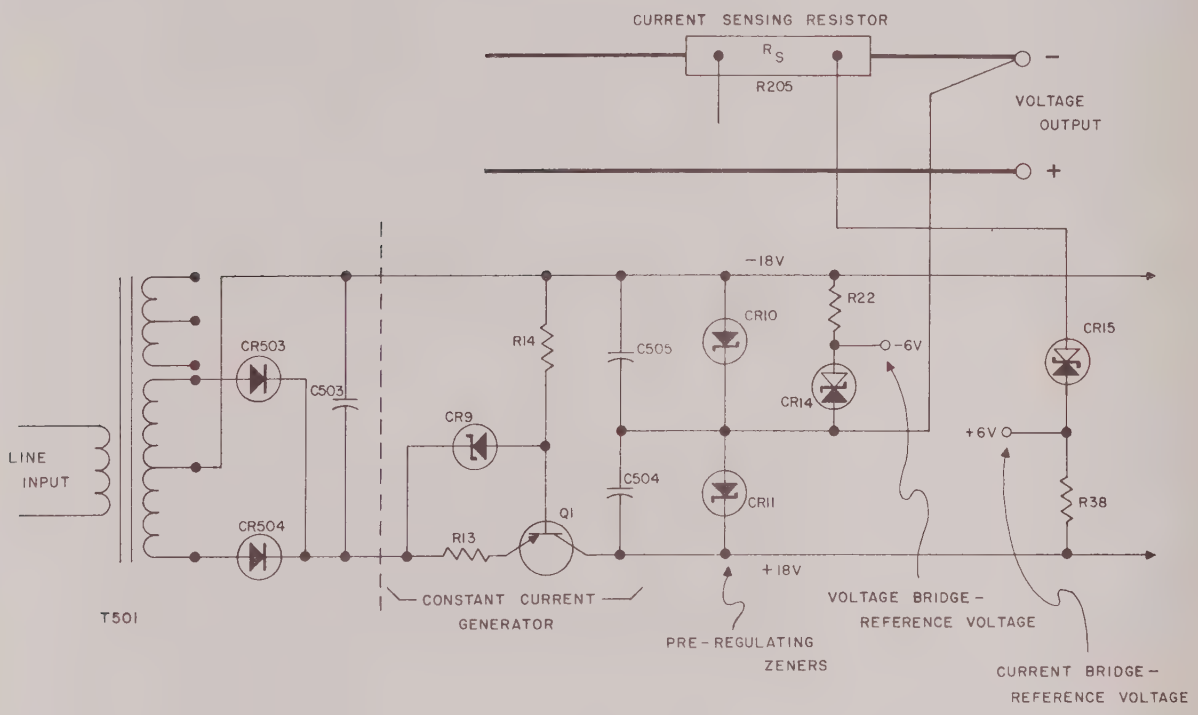
At the start of the timing cycle a synchronizing pulse from Q301 discharges C306 at a time coincident with the zero crossover of the input sine wave power. The source for this synchronizing signal is the positive excursions of voltage developed across zener clipper CR307 from a full wave rectified voltage in phase with the voltage applied to the SCR.

Controls R311 and R322 are factory adjustments. R311 sets the voltage across the pass elements. R322 is set to minimize the variation in this voltage over the specified change of input line voltage. (See schematic diagram).





TIMING WAVEFORM
(IDEALIZED)



Rectified and filtered DC is applied to a constant current generator consisting of regulating transistor Q1 and associated components. The regulated voltage across Zener CR9 controls Q1 to maintain this voltage across R13. Constant current must, therefore, flow through R13, Q1, and the connected circuits. With constant current flowing through CR11 and CR10 a -18 volts and + 18 volts source is developed, independent of line variations.

Regulated current flows through temperature compensated Zeners CR14 and CR15 through respective resistors R22 and R38. These Zeners provide the reference voltage for the voltage bridge and current bridge respectively.

The ± 18 volts source serves also as the operating voltages for the control amplifiers.

SECTION 4.0 POWER SUPPLY MEASUREMENTS

Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or repair check. Since these measurements require special techniques to insure correct results, suggestions for their performance are included herewith.

Required Instrumentation:

1) A constant AC supply voltage with provisions for adjusting or "stepping" the voltage over a specified region (105-125 volts). A variable auto-transformer is generally adequate, if it is rated to deliver the input current requirements of the power supply without significant change in output voltage.

2) A resistor load, or equal, to fully load the supply at constant voltage or fully absorb the compliance voltage at constant current. Provisions for on-off switching is desirable.

3) Voltage Monitor -

   a) A differential voltmeter with a resolution of 1 millivolt or better, or a power supply analyzer such as the Kepco Regulation Analyzer, Model 901C, which displays the regulation percentage directly.

or b) A DC coupled oscilloscope with better than 1 millivolt per centimelts deflection sensitivity and a suitable "buck-out" voltage source of equal magnitude and comparable or better stability than the voltage under test.

The FOUR-TERMINAL NETWORK is an essential device for precise measurement of regulation. In Figure 1 is shown the location of sensing leads for

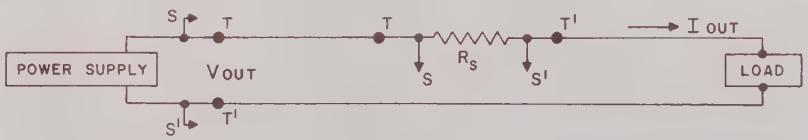


Figure 1 VOLTAGE AND CURRENT SENSING

Proper monitoring of output voltage or load current (voltage drop across sensing resistor, R_S). It is to be noted that the sensing leads (S)(S') for V out are connected to the power supply side of output terminals (T) (T'), and for I out, across the current sensing resistor, R_S, within R_S terminal connections (T)(T'). The function of the four-terminal network (T)(T') - (S)(S') is the elimination of contact resistance at (T)(T') from the sensing circuit. This resistance is of significant magnitude at moderate to high currents where a high order of regulation measurement is to be made.

VOLTAGE REGULATION is defined as the amount of output voltage change resulting from a specified change of line voltage or output load. The measurement is made at the rear terminals of the power supply in the manner shown in Figure 2, which is a practical compromise to the requirement of a 4-terminal network.

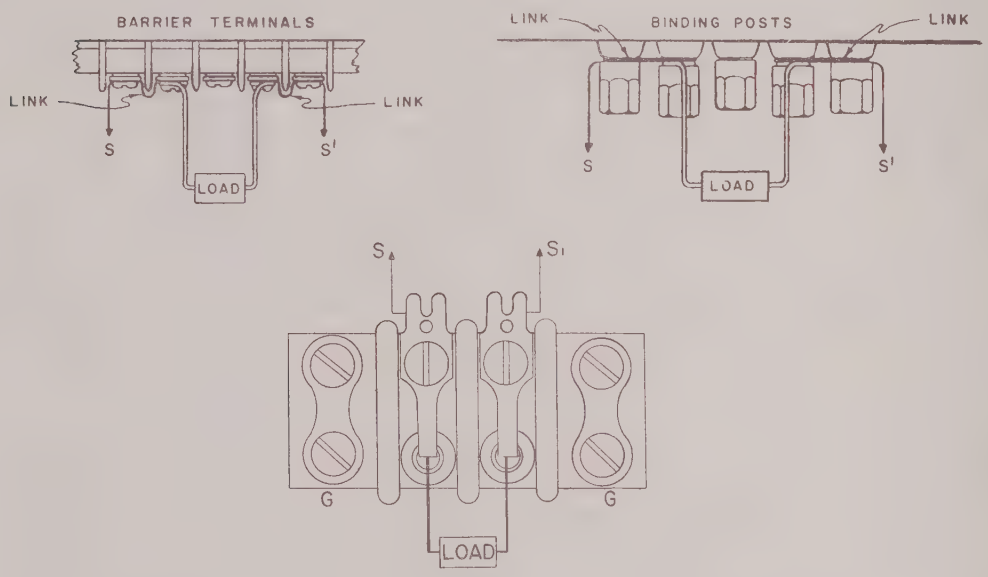


Figure 2

CURRENT REGULATION is defined as the amount of current change resulting from a specified change in line voltage or output load. The measurement is made by monitoring the drop across a sensing resistor that develops approximately one volt. This resistor must be selected for low temperature coefficient and high wattage - over ten times the actual wattage - to reduce changes in the sensing resistance resulting from heating. Consideration must be given to current drawn by devices connected to the power supply terminals other than the useful load through which constant current is desired. Such devices will degrade current regulation. External voltmeters should be of the high impedance type with higher than 100 megohms input.

RIPPLE - An oscilloscope or true RMS indicating meter may be used with consideration given to DC blocking (a 0.1 mfd capacitor of suitable voltage is generally adequate). The peak-to-peak oscilloscope measurement divided by 3 is reduced to an RMS value to a first order approximation if the observed signal approaches a sine waveform.

kepco inc. REPLACEMENT PARTS LIST

POWER SUPPLY MODEL KS 60-20M Code 1-665

SCHEMATIC NO.	QTY	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
B201-203	3	Motor	Barber Colman KYAF764-1	148-0006
C201	1	Capacitor, Mylar, Film 0.01 µf, 200 v, 20%	Sprague Electric 192P10302	117-0353
C202-205, 208, 209	6	Capacitor, Electrolytic, Can 17 K µf, 75 v	General Electric 43F3250CA6	117-0397
C206	1	Capacitor, Electrolytic, Tubular 500 µf, 150 v	General Electric 43F7448AA1	117-0426
C207	1	Capacitor, Electrolytic, Can 550 µf, 100 v	General Electric 43F7447AA1	117-0425
C210, 211	2	Capacitor, Mylar, Pigtail 0.22 µf, 400 v, 20%	Good All 663UW	117-0338
C212, 213	2	Capacitor, Mylar, Pigtail 1 µf, 400 v, 10%	TRW 663F10594W	117-0394
CB101	1	Switch, Circuit Breaker	Heinemann Electric AM46	~~127-0161~~ 127-0156
CR201	1	Rectifier Assembly Includes the following:	Kepco Inc.	124-0220
CR603, 604	2ea.	Rectifier, Silicon, Stud	Motorola 1N3210	124-0165
CR605, 606	2ea.	Rectifier, Silicon, Control, Stud	General Electric ZJ246B	124-0143
R601, 602	2ea.	Resistor, Fixed, Molded 220 ohm, 1/2 w, 10%	Allen Bradley EB2211	115-0371
DS101, 102	2	Pilot Light Assembly	Drake Mfg. 7-503	152-0071
F101	1	Fuse, Slo Blo 2/10 a, 250 v	Bussman MDL-2/10	141-0022
L201	1	Choke	Kepco Magnetics	100-1457
*M101	1	Meter 0-60 v DC	General Electric 8DW91V202AR2	135-0149
*M102	1	Meter 0-20 a, 50 mv	General Electric 8DW91A475CL2	135-0235
R101	1	Resistor, Variable 6.5 K ohm	IRC Model 8000	115-1450
R102	1	Resistor, Variable 50 ohm	IRC Model 8000	115-1448
R201	1	Resistor, Fixed, Power, Strip 15 ohm, 10 w, 5%	Hardwick Hindle B352	115-1418
R202, 204	2	Resistor, Fixed, Power, Strip 200 ohm, 40 w, 5%	Ward Leonard 40S200	115-0593

*Metered Models Only.

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc. REPLACEMENT PARTS LIST

POWER SUPPLY MODEL KS 60-20M Code 1-665

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R203	1	Resistor, Fixed, Power, Strip 75 ohm, 10 w, 5%	Ohmite Mfg. F112	115-0866
R205	1	Resistor, Sensing 0.025 ohm, 1%	Kepco Inc.	115-1671
R206, 208	2	Resistor, Fixed, Power, Strip 2 K ohm, 20 w, 5%	Ward Leonard 20S2000	115-0701
R207	1	Resistor, Fixed, Power, Strip 7.5 ohm, 20 w, 5%	Ward Leonard 2" ministrip-75	115-0811
R209, 210	2	Resistor, Fixed, Power, Strip 8 K ohm, 10 w, 5%	Hardwick Hindle	115-1579
R211	1	Resistor, Fixed, Power, Strip 1 K ohm, 20 w, 5%	Ward Leonard 20S1000	115-0611
R212	1	Resistor, Fused, Oxide 62 K ohm, 1/2 w, 5% (Non-Metered Only)	Corning Glass C20	115-1459
T201	1	Transformer, Power	Kepco Magnetics	100-1423
A901, 902, 904-906	5	Pass Assembly Includes the following:	Kepco Inc.	110-0214
	2ea.	Transistor, PNP	Delco	**119-0016
	2ea.	Resistor, Fixed, Precision, WW 0.1 ohm, 5 w, 3%	Tepro Electric TS5W	115-1355
A903	1	Pass Assembly Includes the following:	Kepco Inc.	110-0213
	2ea.	Transistor, PNP	Delco	**119-0016
	2ea.	Resistor, Fixed, Precision, WW 0.1 ohm, 5 w, 3%	Tepro Electric TS5W	115-1355
	1ea.	Thermostat N.C. 80° ±3%	Chatham Controls DRSCORP80CS	127-0190
A907	1	Driver Assembly Includes the following:	Kepco Inc.	110-0215
	1ea.	Transistor, PNP	Delco	**119-0016
	1ea.	Resistor, Fixed, Molded 47 ohm, 2 w, 10%	Allen Bradley HB4701	115-0322
A908	1	Driver Assembly Includes the following:	Kepco Inc.	110-0216
	2ea.	Transistor, PNP	Delco	**119-0016
	1ea.	Resistor, Fixed, Power, Axial 500 ohm, 3 w, 5%	Ward Leonard 3X500	115-0459

**See Field Replacement Page.

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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kepco inc. REPLACEMENT PARTS LIST

CONTROL BOARD ASSEMBLY PCB#1 MODEL KS 60-20M Code 12-2364

SCHEMATIC NO.	QTY	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C7	1	Capacitor, Mylar 0.4 µf, 200 v, 10%	Hopkins Eng. P42MK	117-0128
C9	1	Capacitor, Mylar 0.2 µf, 200 v, 10%	Hopkins Eng. P22MK	117-0236
C10, 11, 13	3	Capacitor, Mylar, Pigtail 0.5 µf, 300 v, 20%	Good All X663F	117-0332
CR9, 12	2	Zener Diode	Transitron SV125	121-0028
CR10, 11	2	Zener Diode	Motorola 1N3026B	121-0036
CR14, 15	2	Zener Diode	International Rect. 1N821	121-0041
CR16, 17	2	Rectifier, Silicon, Pigtail	Electronic Devices CEC1000	124-0178
Q1	1	Transistor, PNP	Delco	**119-0016
Q2, 7, 8, 10-13	7	Transistor, Silicon, NPN	General Electric	**119-0054
Q3, 4, 5, 6, 9	5	Transistor, Silicon, PNP	Hughes	**119-0055
R13	1	Resistor, Fixed, Power, Axial 125 ohm, 3 w, 5%	Tepro Electric TS3C	115-1467
R14	1	Resistor, Fixed, Power, Axial 6 K ohm, 3 w, 3%	Hardwick Hindle 9/16 GA6K LTC	115-1155
R15	1	Resistor, Fixed, Molded 560 ohm, 1/2 w, 10%	Allen Bradley EB5611	115-0451
R16, 56	2	Resistor, Fixed, Precision, WW 36 K ohm, 2 w, 5%	Tepro Electric TS2C	115-1313
R17	1	Resistor, Fixed, Molded 100 ohm, 1/2 w, 10%	Allen Bradley EB1011	115-0626
R18	1	Resistor, Fixed, Molded 430 ohm, 1/2 w, 5%	Allen Bradley EB4315	115-0581
R19, 37	2	Resistor, Fixed, Precision, WW 10 ohm, 3 w, 5%	Ward Leonard 3X10	115-0421
R20	1	Resistor, Fixed, Precision, WW 13 K ohm, 1 w, 5%	Tepro Electric TS1W	115-1309
R21, 35	2	Resistor, Fixed, Precision, WW 1.2 K ohm, 1 w, 5%	Tepro Electric TS1W	115-1306
R22, 38	2	Resistor, Fixed, Precision, WW 510 ohm, 1 w, 1%	Tepro Electric TS1W	115-1466
R23	1	Resistor, Fixed, Molded 1.1 K ohm, 1/2 w, 5%	Allen Bradley EB1125	115-0448

**See Field Replacement Page.

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SCHEMATIC NO.	QTY	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R24	1	Resistor, Fixed, Molded 12 K ohm, 1/2 w, 10%	Allen Bradley EB1231	115-1168
R25	1	Resistor, Fixed, Molded 1 K ohm, 1/2 w, 5%	Allen Bradley EB1021	115-0547
R27	1	Resistor, Fixed, Molded 5.6 K ohm, 1/2 w, 10%	Allen Bradley EB5621	115-1201
R28	1	Resistor, Fixed, Precision, W.W. 570 ohm, 1 w, 1%	Tepro Electric TS1W	115-1465
R31	1	Resistor, Fixed, Molded 68 ohm, 1/2 w, 5%	Allen Bradley EB6805	115-0904
R32	1	Resistor, Fixed, Molded 1.8 K ohm, 1/2 w, 10%	Allen Bradley EB1821	115-0473
R33	1	Resistor, Fixed, Precision, W.W. 6.2 K ohm, 1 w, 5%	Tepro Electric TS1W	115-1335
R34	1	Resistor, Fixed, Precision, W.W. 2.5 K ohm, 1 w, 5%	Tepro Electric TS1W	115-1307
R36	1	Resistor, Fixed, Precision, W.W. 10 K ohm, IN, 1%	Tepro Electric TS-1W	115-1232
R40	1	Resistor, Variable 150 ohm, 1/2 w, 10%	Bourns 3067P-1-151	115-1534
R41	1	Resistor, Fixed, Precision, W.W. 510 ohm, 1 w, 1%	Tepro Electric TS1W	115-1466
R42	1	Resistor, Variable 100 ohm, 1/2 w, 10%	Bourns 3067P-1-10-1	115-1434
R44	1	Resistor, Fixed, Molded 2.7 ohm, 1/2 w, 10%	Allen Bradley EB27G1	115-1595
R46	1	Resistor, Fixed, Molded 510 ohm, 1/2 w, 5%	Allen Bradley EB5115	115-0824
R50, 51	2	Resistor, Fixed, Molded 2.2 K ohm, 1/2 w, 10%	Allen Bradley EB2221	115-0466
R54	1	Resistor, Fixed, Composition 180 K ohm, 1/2 w, 5%	Corning Glass C-20	115-1578
R55	1	Resistor, Fixed, Precision, W.W. 1 ohm, 1 w, 1%	Tepro Electric TS1W	115-1361
R57	1	Resistor, Fixed, Molded 330 ohm, 1/2 w, 10%	Allen Bradley EB3311	115-0804
R61	1	Resistor, Fixed, Precision, W.W. 5.1 K ohm, 1 w, 1%	Tepro Electric TS-1W	115-1572
R62	1	Resistor, Fixed, Molded 2 K ohm, 1/2 w, 5%	Allen Bradley EB2025	115-0520
R52, 59	2	Resistor, Fixed, Molded 100 ohm, 1/2 w, 5%	Allen Bradley EB1015	115-0341

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REPLACEMENT PARTS LIST

SCR CONTROL BOARD PCB#2 MODEL KS 60-20M — Code 4-965 —

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C303	1	Capacitor, Mylar, Pigtail 0.25 µf, 200 v, 20%	Hopkins Eng. P252M	117-0378
C305, 306, 311, 314	4	Capacitor, Mylar, Pigtail 0.1 µf, 200 v, 10%	Hopkins Eng. P12M	117-0363
C307, 310	2	Capacitor, Mylar, Pigtail 0.5 µf, 300 v, 10%	Good All X663F	117-0332
C308	1	Capacitor, Mylar, Pigtail 0.1 µf, 600 v, 20%	TRW Type 663F	117-0316
C312	1	Capacitor, Mylar 1 µf, 200 v, 10%	Hopkins Eng. 1P2MK	117-0207
CR306	1	Rectifier, Silicon, Pigtail	Semicon Inc. SM-140	124-0028
CR307	1	Zener Diode	Transitron SV125	121-0028
CR308	1	Zener Diode	Motorola 1N3026B	121-0036
CR309, 310	2	Rectifier, Silicon, Pigtail	Semicon Inc. SM-110	124-0133
Q301	1	Transistor, Silicon, NPN	General Electric	**119-0054
Q302	1	Transistor, Unijunction	General Electric	**119-0048
Q303, 304	2	Transistor, Silicon, PNP	Hughes	**119-0055
R302	1	Resistor, Fixed, Molded 10 K ohm, 1 w, 10%	Allen Bradley GB1031	115-0040
R303	1	Resistor, Fixed, Molded 8.2 K ohm, 1/2 w, 10%	Allen Bradley EB8221	115-1169
R305	1	Resistor, Fixed, Power, Axial 30 ohm, 3 w, 5%	Ward Leonard 3X30	115-0773
R306	1	Resistor, Fixed, Molded 15 K ohm, 1/2 w, 10%	Allen Bradley EB1531	115-1152
R307	1	Resistor, Fixed, Power, Axial 2 K ohm, 5 w, 5%	Ward Leonard 5X2000	115-0568
R308	1	Resistor, Fixed, Molded 470 ohm, 1/2 w, 5%	Allen Bradley EB4715	115-0919
R309	1	Resistor, Fixed, Molded 330 ohm, 1/2 w, 10%	Allen Bradley EB3311	115-0804
R310	1	Resistor, Fixed, Molded 3.3 K ohm, 1/2 w, 10%	Allen Bradley EB3321	115-0439
R311	1	Resistor, Variable 5 K ohm, 1/2 w, 10%	Bourns 3067S-1-502	115-1363

**See Field Replacement Page.

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REPLACEMENT PARTS LIST

SCR CONTROL BOARD PCB #2 MODEL KS-60-20M Code 10-2164

SCHEMATIC NO.	QTY	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R312	1	Resistor, Fixed, Molded 2.2 K ohm, 1/2 w, 10%	Allen Bradley EB2221	115-0466
R313, 314	2	Resistor, Fixed, Molded 10 K ohm, 1/2 w, 10%	Allen Bradley EB1031	115-0489
R318	1	Resistor, Fixed, Molded 10 ohm, 1/2 w, 10%	Allen Bradley EB1001	115-0502
R319	1	Resistor, Fixed, Molded 1 K ohm, 1/2 w, 10%	Allen Bradley EB1021	115-0547
R321	1	Resistor, Fixed, Molded 150 ohm, 1/2 w, 10%	Allen Bradley EB1511	115-0543
R322	1	Resistor, Variable 500 ohm, ½ w, 20%	Allen Bradley FR500M	115-1501
R323	1	Resistor, Fixed, Molded 120 ohm, 1/2 w, 5%	Allen Bradley EB1215	115-0903

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kepco inc REPLACEMENT PARTS LIST

REFERENCE ASS'Y, PCB#3, ASS'Y A5, KS 60-20(M) Code 9-2965

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C501	1	Capacitor, Electrolytic, Pigtail 20 µf, 150 v	General Electric 43F2271AA2	117-0145
C502	1	Capacitor, Electrolytic, Pigtail 1 K µf, 10 v	General Electric 43F2381AA2	117-0176
C503	1	Capacitor, Electrolytic, Pigtail 150 µf, 75 v	General Electric 43F7147AA1	117-0388
C504, 505	2	Capacitor, Electrolytic, Pigtail 22 µf, 25 v	General Electric 76F02KE.26	117-0503
C506	1	Capacitor, Electrolytic, Pigtail 500 µf, 50 v	General Electric 43F2528AA1	117-0221
CR501, 503, 504	3	Rectifier, Silicon, Pigtail	Semicon Inc. SM-140	124-0028
CR502, 505, 506, 508, 509, 510	6	Rectifier, Silicon, Pigtail	Semicon Inc. SM-110	124-0133
CR507	1	Zener Diode	Hoffman 1N1773	121-0012
K501	1	Relay, 3PDT	Omega 200PC3CX	140-0040
R501	1	Resistor, Fixed, Molded 100 K ohm, 1/2 w, 10%	Allen Bradley EB1041	115-0809
R502	1	Resistor, Fixed, Power, Axial 1 K ohm, 5 w, 5%	Ward Leonard 5X1000	115-0512
R503	1	Resistor, Power, Axial 2.5 K ohm, 3 w, 5%	Ward Leonard 3X2500	115-0469
R504	1	Resistor, Fixed, Molded 47 ohm, 1/2 w, 10%	Allen Bradley EB4701	115-0718
R505	1	Resistor, Fixed, Power, Axial 2 K ohm, 5 w, 5%	Ward Leonard 5X2000	115-0568
T501	1	Transformer	Kepco Magnetics	100-1538

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REPLACEMENT PARTS LIST

AUXILIARY CONTROL ASSEMBLY PCB#4 MODEL KS 60-20M Code 10-2164

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C401,402	2	Capacitor, Electrolytic, Pigtail 1 K µf, 6 v	Industrial Cond. 1B1382RM	117-0346
C403	1	Capacitor, Mylar, Pigtail 1 µf, 200 v, 10%	Hopkins Eng. 1P2MK	117-0207
CR401,402	2	Rectifier, Silicon, Pigtail	Semicon Inc. SM-140	124-0028
CR403	1	Rectifier, Silicon, Pigtail	Semicon Inc. SM-110	124-0133
CR404	1	Zener Diode	Motorola 10M82Z	121-0032
CR405	1	Zener Diode	Hoffman 1N1766	121-0021
Q401	1	Transistor, Silicon, PNP	Hughes	**119-0055
R401	1	Resistor, Fixed, Molded 39 K ohm, 2 w, 10%	Allen Bradley HB3931	115-0258
R402	1	Resistor, Variable, Comp. 50 K ohm, 2 w, 10%	Allen Bradley JA1L040S503UZ	115-0437
R403	1	Resistor, Fixed, Molded 10 K ohm, 1/2 w, 10%	Allen Bradley EB1031	115-0489
R404	1	Resistor, Variable, Comp. 100 ohm, 2 w	Allen Bradley JA1L040S101UZ	115-1540
R405	1	Resistor, Fixed, Power, Axial 100 ohm, 3 w, 5%	Ward Leonard 3X100	115-0471
R406	1	Resistor, Fixed, Power, Axial 450 ohm, 3 w, 5%	Hardwick Hindle 9/16 GA 450	115-1231
R408,409	2	Resistor, Fixed, Power, Axial 3 ohm, 3 w, 5%	Ward Leonard 3X3	115-0580

**See Field Replacement Page

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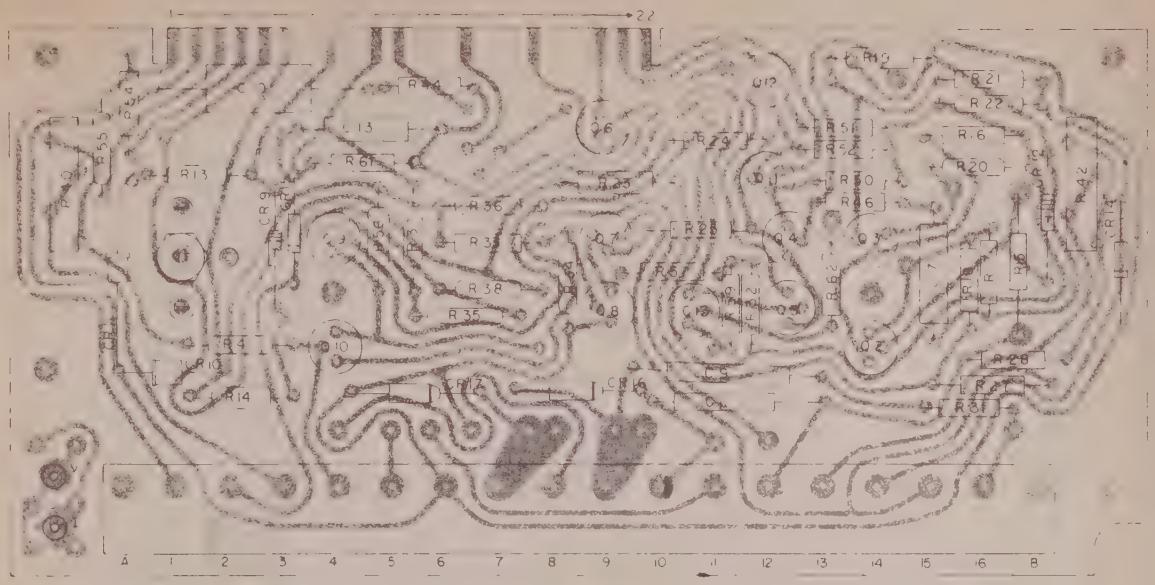
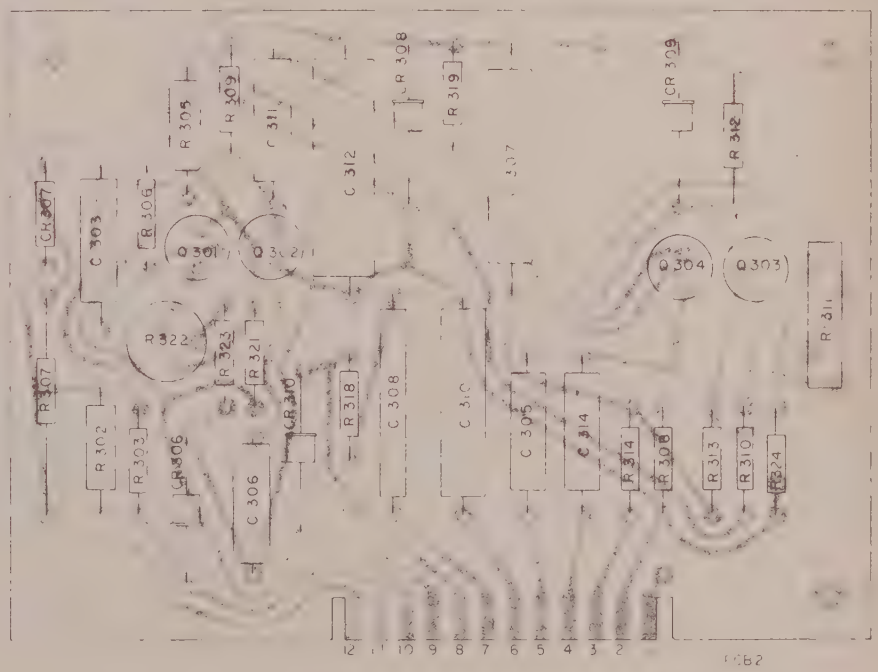
FIELD REPLACEMENT LIST

Kepco Part No.	Description	Recommended Replacement MFR.	MFR. No.
119-0016	Transistor, PNP	Delco	2N174
119-0020	Transistor, PNP	RCA	2N398A
119-0022	Transistor, PNP	Tung Sol Texas Instrument	2N1707 2N404
119-0024	Transistor, NPN	General Inst. RCA, General Elec. Texas Instrument Sylvania, Texas Instrument	2N1605 2N388 2N1308
119-0034	Transistor, PNP	Delco Hughes	2N1172 2N1131A
119-0035, 0036,0037	Transistor, PNP	Motorola Clevite	2N1167 CTP 3553
119-0038	Transistor, NPN	Transitron	ST29
119-0048	Transistor, Unijunction	General Electric	2N1671A
119-0049	Transistor, PNP	Delco	2N669
119-0054	Transistor, NPN	General Electric	2N338 2N336A
119-0055	Transistor, PNP	Hughes	2N1131A
119-0056	Transistor, NPN	General Electric	2N336A
119-0057	Transistor, PNP	Delco	DTG-1200
119-0059	Transistor, NPN	RCA	2N3053
119-0060	Transistor, NPN	RCA	2N3054
119-0061	Transistor, NPN	RCA	2N3055
119-0065	Transistor, PNP	Hughes	2N3225
119-0067	Transistor, PNP	Delco	DTG-2400
119-0068	Transistor, NPN	RCA	40250
119-0069	Transistor, NPN	RCA	40251
119-0070	Transistor, NPN	RCA	2N3442



PCB



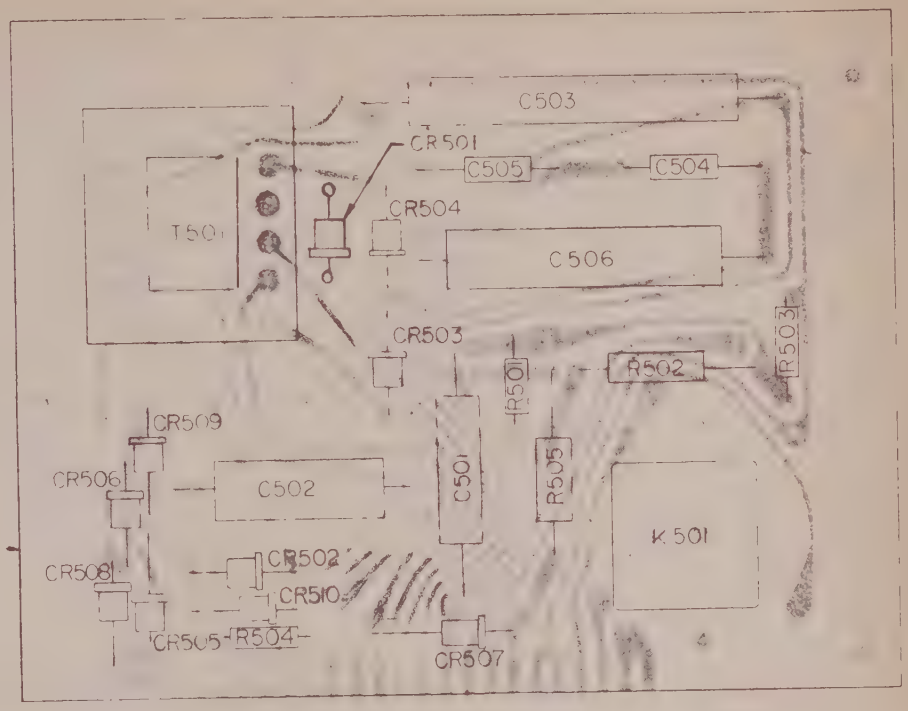
PCB2

DRAWN	CHECKED	APPROVED	DATE
B.D.P.			9-13-65
MODEL NO. KS 60-20M		PART NO.	SCALE

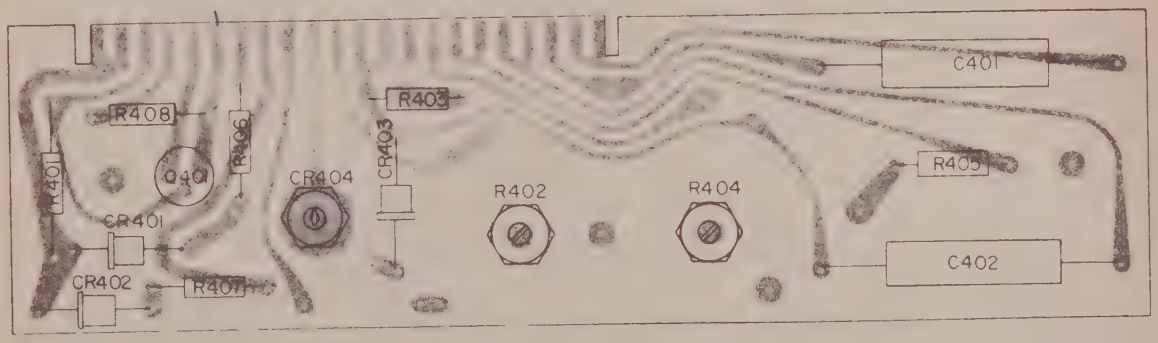
KEPCO INC.
FLUSHING, N.Y.

TITLE PCB-1, PCB-2
COMPONENT LOCATION

DWG. NO.

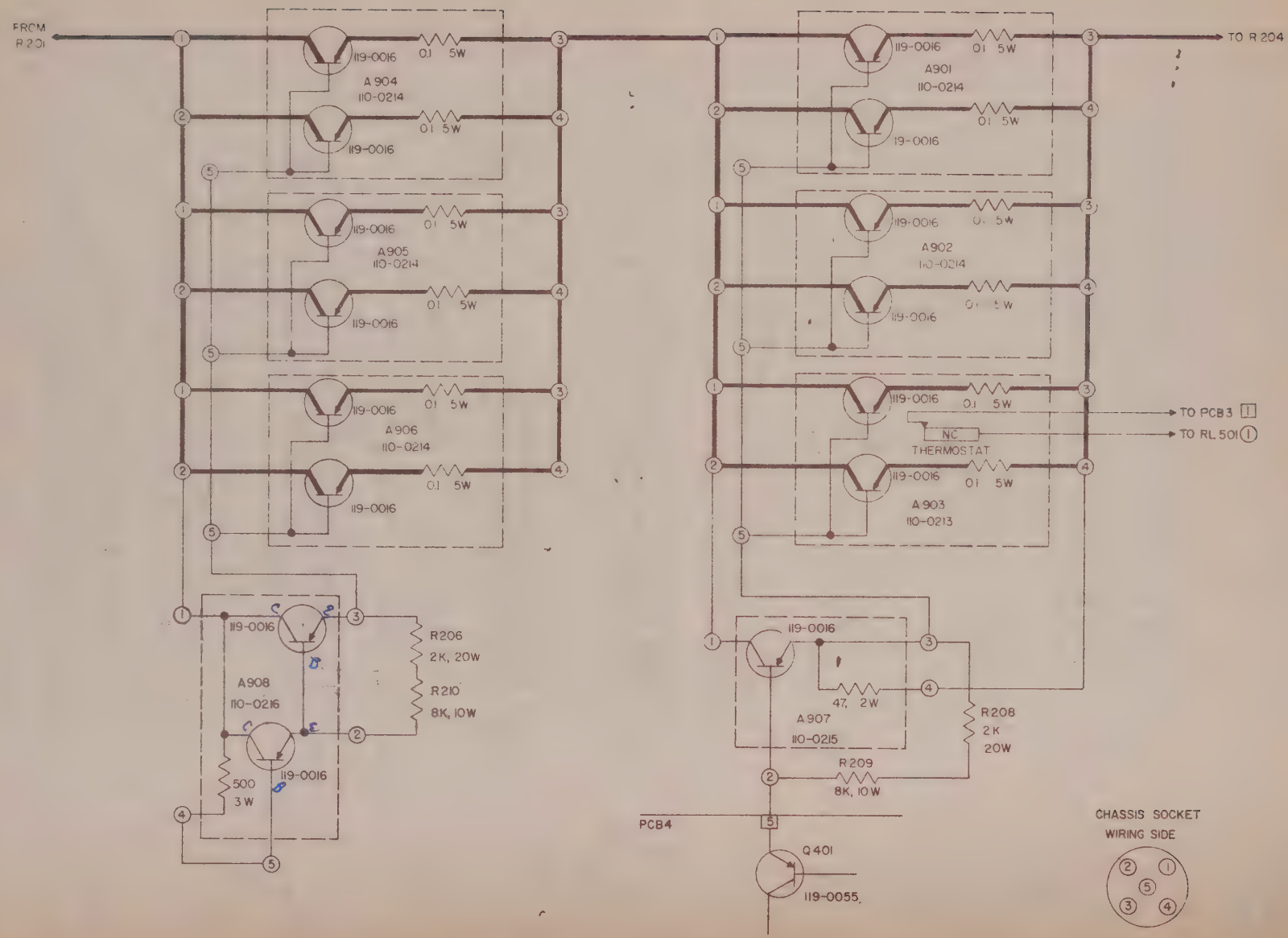


PCB-3



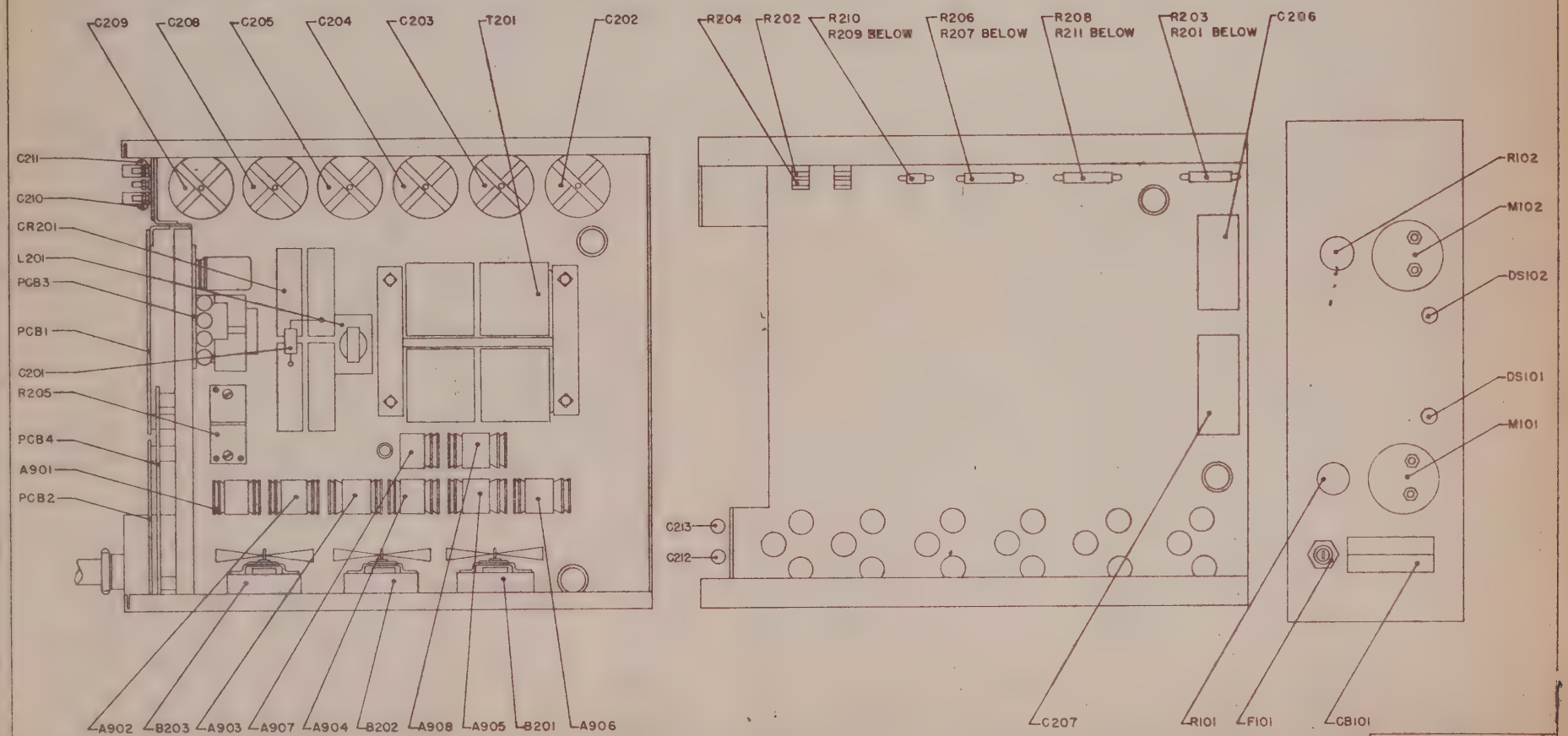
PCB-4

DRAWN	CHECKED	APPROVED	DATE	KEPCO INC.
B.D.P.	REC	JB	9-13-65	FLUSHING, N.Y.
MODEL NO. KS60-20M		PART NO.	SCALE #	
TITLE PCB-3, PCB-4 COMPONENT LOCATION				DWG. NO.



KS 60-20M PASS ASSEMBLY DETAIL

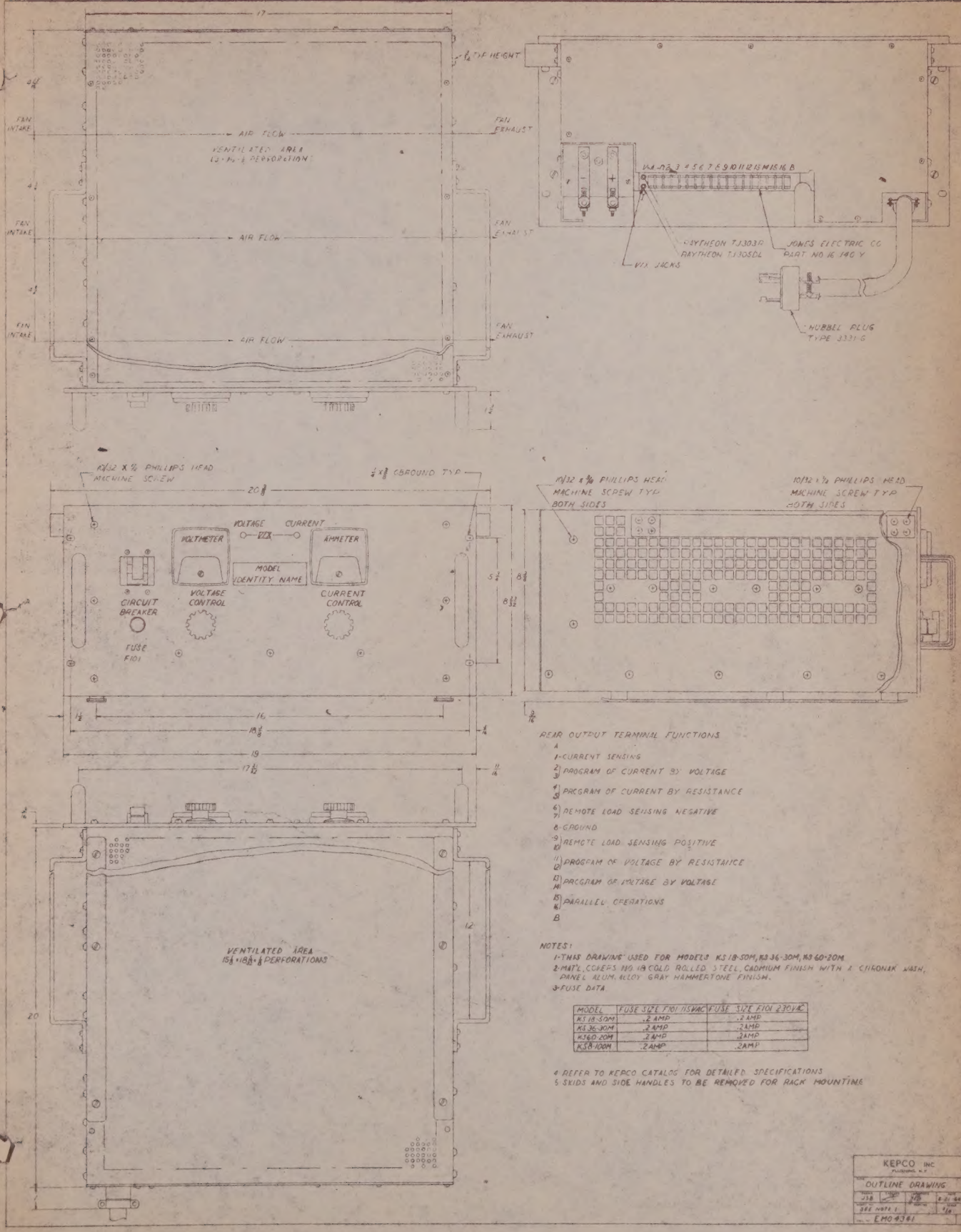
DM04350



KEPCO INC.
FLUSHING, N.Y.

TITLE: COMPONENT LOCATION

DRAWN	CHECKED	APPROVED	DATE
JSB			1-6-65
MODEL NO.		PART NO.	SCALE
KS 60-20M			NONE
DWG. NO.	DM04350		



REAR OUTPUT TERMINAL FUNCTIONS

A

1-CURRENT SENSING

2/3 PROGRAM OF CURRENT BY VOLTAGE

4/5 PROGRAM OF CURRENT BY RESISTANCE

6/7 REMOTE LOAD SENSING NEGATIVE

8-GROUND

9/10 REMOTE LOAD SENSING POSITIVE

11/12 PROGRAM OF VOLTAGE BY RESISTANCE

13/14 PROGRAM OF VOLTAGE BY VOLTAGE

15/16 PARALLEL OPERATIONS

B

NOTES:

1-THIS DRAWING USED FOR MODELS KS 18-50M, KS 36-30M, KS 60-20M

2-MAT'L, COVERS NO. 19 COLD ROLLED STEEL, CADMIUM FINISH WITH A CHROMAK WASH, PANEL ALUM. ALLOY GRAY HAMMERTONE FINISH.

3-FUSE DATA

MODEL	FUSE SIZE F101 115VAC	FUSE SIZE F101 230VAC
KS 18-50M	.2 AMP	.2 AMP
KS 36-30M	.2 AMP	.2 AMP
KS 60-20M	.2 AMP	.2 AMP
KS 8-100M	.2 AMP	.2 AMP

4 REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS

5 SKIDS AND SIDE HANDLES TO BE REMOVED FOR RACK MOUNTING

KEPCO INC
FLUSHING, N.Y.

OUTLINE DRAWING

SIZE	CAGE CODE	REV	
J18			8-31-64
SCALE		SHEET	
SEE NOTE 1		1 OF 1	

EMO-4341

kepco

INSTRUCTION MANUAL CORRECTION

Please note the following corrections to the Manual Material as indicated:

Parts List & Schematic Diagram:

1. Change R305 Resistor, Fixed, Power, Axial 30 ohm, 3 w, 5% Kepco #115-0773 to:
   R305 Resistor, Fixed, Power, Axial 20 ohm, 3 w, 5% Kepco #115-0851.

2. Change R323 Resistor, Fixed, Molded 120 ohm, 1/2 w, 10% Kepco #115-0903 to:
   R323 Resistor, Fixed, Molded 1.5 K ohm, 1/2 w, 5% Kepco #115-0442.

3. Change R306 Resistor, Fixed, Molded 15 K ohm, 1/2 w, 10% Kepco #115-1152 to:
   R306 Resistor, Fixed, Molded 9.1 K ohm, 1/2 w, 5% Kepco #115-1727.

4. Change C303 Capacitor, Mylar, Pigtail 0.25 µf, 200 v, 20% Kepco #117-0378 to:
   C303 Capacitor, Mylar, Pigtail 0.02 µf, 200 v, 10% Kepco #117-0377.

5. Change R201 Resistor, Fixed, Power, Strip 15 ohm, 10 w, 5% Kepco #115-1418 to:
   R201 Resistor, Fixed, Power, Strip 7.5 ohm, 10 w, 5% Kepco #115-1425.

6. Change CB101 Switch, Circuit Breaker Kepco #127-0161 to:
   CB101 Switch, Circuit Breaker Kepco #127-0156.

7. Change 1, A903 Pass Assembly Kepco Inc. 110-0213 to:
   1, A903 Pass Assembly Kepco Inc. 110-0225
   Includes the following:

2ea.	Transistor, PNP	Delco	119-0016
2ea.	Resistor, Fixed, Power, Axial 0.1 ohm, 5 w, 5%	Tepro Electric TS5W	115-1355
1ea.	Thermostat 80°C ±3%	Chatham Controls DRPCCRP80C	127-0165

COMPONENT LOCATION - 6M04363 - PCB-1

Change F1 Fuse, Pigtail 1/20 A Kepco #141-0060 to:
R15 Resistor, Fixed, Molded 560 ohm, 1/2 w, 10% Kepco #115-0451.

KS 60-20M/7-2065
8-1965/r12 C1311
9-13/65/r12A C1251

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#146-0045